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1.	Your reference	P24437GB-02/IK/CEW
2.	Patent application number *(The Patent Office will fill this part in)*	0425943.8
3.	Full name, address and postcode of the or of each applicant *(underline all surnames)*	Pvaxx Research and Development Limited Unit 4 Dovecot Workshops Barnsley Park Estate Barnsley, Near Cirencester Gloucestershire GL7 5EG United Kingdom
	Patents ADP number *(if you know it)*	8902645001
	If the applicant is a corporate body, give the country/state of its incorporation	United Kingdom
4.	Title of the invention	Load-Carrying Apparatus
5.	Name of your agent *(if you have one)*	Mathys & Squire
	"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	~~100 Gray's Inn Road~~ ~~London WC1X 8AL~~ ~~United Kingdom~~ 120 Holborn London EC1N 2SQ
	Patents ADP number *(if you know it)*	1081001

6. Priority: Complete this section if you are declaring priority from one or more earlier patent applications, filed in the last 12 months.

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*
United Kingdom	0406272.5	19 March 2004
United Kingdom	0414991.0	2 July 2004

7. Divisionals, etc: Complete this section only if this application is a divisional application or resulted from an entitlement dispute (see note f)

Number of earlier UK application	Date of filing *(day / month / year)*

8. Is a Patents Form 7/77 (Statement of inventorship and of right to grant of a patent) required in support of this request? — YES

Answer YES if:

a) any applicant named in part 3 is not an inventor, or
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c) any named applicant is a corporate body.

Otherwise answer NO (See note d)

9. Accompanying documents: A patent application must include a description of the invention. Not counting duplicates, please enter the number of pages of each item accompanying this form:

Continuation sheets of this form	–
Description	69
Claim(s)	23
Abstract	0
Drawing(s)	46+46

10. If you are also filing any of the following, state how many against each item.

Priority documents	–
Translations of priority documents	–
Statement of inventorship and right to grant of a patent (Patents Form 7/77)	–
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Any other documents (please specify)	–

11. I/We request the grant of a patent on the basis of this application.

Signature(s) Mathys & Squire Mathys & Squire Date 25 NOVEMBER 2004

12. Name, daytime telephone number and e-mail address, if any, of person to contact in the United Kingdom

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Load-Carrying Apparatus

The present invention relates to the field of load-carrying apparatus, for example for the storage and transportation of goods, including methods for manufacturing such apparatus. In particular, but not exclusively, the invention relates to apparatus such as freight containers, pallets and cable reels and methods for manufacturing the apparatus.

Apparatus for storing and transportation of goods, particularly bulk goods, has to be robust enough to withstand the high impact stresses and adverse environmental conditions that it may encounter during normal operation.

Wooden pallets for storing and transporting goods are well known in the art and are defined by standards such as ISO Standard No. 6780. Such pallets are strictly defined in the standard, and other standards define the tests to which they must be subjected before being judged to be fit for use.

However, wooden pallets suffer from a number of disadvantages. They are susceptible to rotting, and woodworm, which means that their working life is relatively short, and they may endanger the goods carried on them. They are relatively easy to pierce with sharp objects, relatively heavy, and difficult to recycle.

Plastics pallets have been proposed, for example in co-pending application 0406272.5, but these have their own problems, in particular no plastic pallet has yet been judged by manufacturers to be strong and durable enough for their needs. One problem is the paucity of tests available for plastic pallets and another is that tests for wooden pallets are unsuitable as they do not tests properties of plastic pallets (for example fracture strength) which are irrelevant for wooden pallets.

Aspects of the invention are set out in the independent claims and preferred features are set out in the dependent claims. Aspects may be provided separately or in combination and features of one aspect may be applied to other aspects. Modifications, which would be obvious to one skilled in the art, may further be provided within the scope of the invention.

According to one aspect, there is provided a pallet comprising a top pallet element and a bottom pallet element, wherein each pallet element comprises a platform and a plurality of pallet feet and wherein each pallet foot comprises an interlocking section, wherein:

in an inverted configuration, the interlocking sections of the top pallet element are arranged to couple with corresponding interlocking sections of the bottom pallet element;

in a stacked configuration, with the pallet elements in substantially the same orientation, at least one pallet element forms a nested configuration when stacked on top of the other pallet element; and wherein the pallet elements are rotationally moulded from a plastics material filled with a mineral filler.

Hence the pallet elements may couple securely to form pallets in one configuration, but nest in a stacked configuration to reduce the space taken up by unloaded pallets. Rotationally moulding the pallet elements using a filled plastics material may provide an efficient way of forming a large number of pallet elements reliably and quickly as described herein.

Preferably, in the nested configuration, the pallet element platforms lie parallel to each other and are closely nested together. Preferably, substantially no gap is left between the pallet element platforms. Preferably, any gap between the platforms is less than around 20mm, preferably less than around 10mm.

In a preferred embodiment, the mineral filler comprises sand. Alternatively, the filler may comprise an ash-based or glass-based filler.

In a highly preferred embodiment, the shape and/or configuration of the top pallet element is different to the shape and/or configuration of the bottom pallet element. As described in more detail below, this may allow the pallet elements to stack and, in particular form a closely nested configuration when stacked in one order, but a less closely nested configuration when stacked in the reverse order. In addition, using different shapes or configurations may enable interlocking elements of one type to be provided on one pallet element and interlocking elements of a different type to be provided on the other pallet element. Providing pallet elements of different shapes may also allow the pallet elements to be provided with different properties. For example, as described in more detail below, the bottom pallet element may be provided with apertures to reduce the weight of the pallet element, whereas the top pallet element may be provided with a continuous surface to allow the storage and transportation of small and/or delicate goods.

Preferably, in a nested configuration, the feet of one pallet element are inserted into recesses in the top surfaces of the corresponding feet of the other pallet element. Hence the feet of at least one type of pallet element may be hollowed from the pallet platform surface.

In one embodiment, the bottom pallet element forms a nested configuration when stacked on top of the top pallet element. In an alternative embodiment, the top pallet element forms a nested configuration when stacked on top of the bottom pallet element.

Preferably, the pallet elements form a nested configuration when one pallet element is stacked on top of the other pallet element but a gap is formed between the stacked pallet elements when the pallet elements are stacked in the reverse order. Hence, if the pallet elements are stacked in a bottom, top, bottom, top configuration, pairs of closely nested pallet elements are separated by gaps. This may advantageously allow the pairs of pallet elements to be separated easily.

In a preferred embodiment, the gap formed between the stacked pallet elements is greater than around 20mm, preferably greater than around 40mm and preferably greater than around 50mm. This may allow the pairs of nested pallet elements to be separated easily and may allow the tines of a fork lift truck to be inserted between the pairs of pallet elements.

In a preferred embodiment, the platform of the bottom pallet element comprises at least one aperture. Preferably, the platform comprises a plurality of apertures. This may reduce the overall weight of the pallet element, and hence the pallet, without significantly reducing the strength of the pallet.

In a preferred embodiment, the feet of the pallet elements are arranged to enable the blades of a forklift truck to engage the pallet from any one of four directions.

In a preferred embodiment, the interlocking sections comprise male or female interlocking sections and, in an inverted configuration, male interlocking sections on one pallet element preferably couple with corresponding female interlocking sections on the other pallet element.

In one embodiment, the interlocking sections of the top pallet element comprise male interlocking sections and the interlocking sections of the bottom pallet element comprise female interlocking sections.

Preferably, at least a portion of each pallet element comprises an outer skin layer.

Further preferably, at least a portion of each pallet element comprises an inner layer having a different composition to the outer skin layer. Further preferably, the inner layer comprises a foamed inner layer.

In a preferred embodiment, the pallet element further comprises a remotely readable tag, preferably an RFID tag or a bar code.

In one embodiment, the platform of the top pallet element comprises a substantially continuous surface.

Preferably, the platform of each pallet element comprises a textured surface.

In a preferred embodiment, the feet of the pallet elements are tapered. This may make it easier to stack and nest the pallet elements and to insert the tines of a fork-lift truck between the pallet feet.

In a preferred embodiment, the interlocking sections of the feet of the pallet elements are arranged so that, on rotation of the bottom pallet element about an axis through the plane of the platform of the bottom pallet element, a male configuration of interlocking sections on the bottom pallet element mates with a female configuration of interlocking sections on the top pallet element and vice versa.

In one embodiment a male interlocking section of a foot comprises one or more protruding elements and a corresponding female interlocking section of a foot comprises one or more hollow sections, wherein the or each hollow section is sized to accommodate the or each protruding element.

In a preferred embodiment, each pallet element is rotationally moulded substantially in one piece.

According to a further aspect there is provided a pallet element comprising a platform having an upper surface and a lower surface and a plurality of feet depending from the lower surface of the platform and wherein:

a single pallet element provides a single-sided pallet having feet of a height sufficient to allow lifting by a forklift truck;

a first said pallet element is arranged to couple to a second said pallet element to provide a double-sided pallet having a total height less than double the height of a single pallet element.

Hence the same pallet elements may be used flexibly, as needed, as single-sided or as double-sided pallets. For example, single-sided pallets may be used for lighter-duty or single-use work and double-sided pallets may be more suitable for heavy-duty work or for repeated use. As described in more detail below, one of the pallet elements is preferably rotated to form the double-sided pallet, so it is clear that, in this orientation, the upper surface of the pallet platform would form the outer surface of the double-sided pallet and would lie below the lower surface.

Preferably, the first and the second pallet elements couple to provide a double-sided pallet wherein the feet of both the first and the second pallet are arranged between the platforms of the pallet elements. Hence one pallet is rotated so that the upper surfaces of the platforms of the pallets form the outer surfaces of the double-sided pallet.

In a preferred embodiment, the pallet elements are arranged to couple on presenting opposed elements appropriately located without further fixings or adhesives. Hence it is straightforward to assemble and dissemble the double-sided pallet.

Providing a single pallet element of a sufficient height to allow lifting by a forklift truck allows the single pallet element to be used alone as a single-sided pallet. Preferably, the height of single pallet element is substantially equal to the height of a standard pallet. The height of a standard pallet defined by the International Organisation for Standardization is defined in ISO Standard No. 6780. Preferably, the height of a single pallet element is at least around 100mm.

Preferably, in a double-sided pallet, the feet of the first pallet element interleave at least partially with the feet of the second pallet element.

In a preferred embodiment, the height of a double-sided pallet is substantially equal to the height of a single-sided pallet. Preferably, the height of a double-sided pallet is substantially equal to the height of a standard pallet. This may allow both double-sided and single-sided pallets to be manoeuvred using the same, standard equipment, for example using a standard forklift truck. Preferably, the height of a double-sided pallet is less than around 200mm.

Further preferably, the difference in height between a double-sided pallet and a single-sided pallet is substantially equal to the height of the platform of a pallet element.

Further preferably, the difference in height between a double-sided pallet and a single-sided pallet is less than the height of the platform of a pallet element.

Preferably, the height of the feet supporting the platform of a single-sided pallet is substantially equal to the spacing between platforms of a double-sided pallet.

Preferably, the first pallet element is coupled to the second pallet element by inserting the feet of at least one pallet element into recesses formed in the lower surface of the platform of the other pallet element. This may allow the heights of the single and double-sided pallets to be substantially the same and may advantageously provide means by which the pallet elements may be coupled together. Preferably, the feet of at least one pallet element latch or clip into the recesses in the lower surface of the other pallet element.

In one embodiment, the recesses in the lower surface of the platform comprise deformable teeth, wherein the deformable teeth latch around the feet of the opposing pallet element to retain the feet in the recesses.

In an alternative embodiment, the feet of each pallet element comprise foot elements, the foot elements of each foot being arranged to interleave with corresponding foot elements in the opposing foot. Hence at least some of the feet may interleave on a microscale with the opposing feet of the other pallet element. For example, the feet may include slots into which corresponding prongs of the feet of the opposing pallet element may be inserted. Pallets may be provided with some feet having foot elements that interleave on the microscale and some feet that interleave on the macroscale as described above.

In a preferred embodiment, at least one foot is arranged substantially at each corner of the platform.

Preferably, at least one foot is arranged substantially at the centre of the platform.

Further preferably, at least one foot is arranged substantially at the centre of each edge of the platform.

In a preferred embodiment, the feet of the pallet elements are arranged so that, on rotation of one pallet element about an axis through the plane of the platform of the pallet, a male configuration of feet on one pallet element mates with a female configuration of feet on the opposing pallet element.

Preferably, at least some of the feet of the pallet are arranged on the platform rotationally asymmetrically about at least one axis of rotation passing through the centre of the plane of the platform of the pallet and parallel to an edge of the pallet.

In one embodiment, one male configuration of feet comprises a single foot and a corresponding female configuration of feet comprises two feet separated by a gap, wherein the gap is sized to accommodate a single foot.

In one embodiment the pallet element is substantially rectangular.

Preferably, when one pallet element is rotated in an axis in the plane of the pallet platform and perpendicular to the elongate axis of the pallet platform, the feet of the pallet element interleave with the feet of a second pallet element.

Preferably, when the first pallet is rotated, the feet of the first pallet are offset relative to the feet of the second pallet.

In one embodiment, a male configuration of feet comprises an odd number of feet and a female configuration of feet comprises an even number of feet.

Preferably, the feet in the male configuration and the feet in the female configuration are mutually offset when a first pallet element is rotated and positioned over a second pallet element so that the platforms are aligned.

In one embodiment, feet in the corners of the pallet comprise male or female configurations of feet and feet in the along the centre lines of the pallet are mutually offset from the centre.

In a preferred embodiment, the pallet elements are rotationally moulded.

Further preferably, each pallet element is rotationally moulded substantially in one piece.

Preferably, the pallet elements are manufactured substantially from a filled plastics material.

Preferably, the filler comprises a mineral filler material.

Advantageously, the feet of each pallet element are formed integrally with the platform of the pallet element.

Preferably, the feet are tapered from a maximum width at the platform of the pallet element. This may allow the feet to be interleaved or stacked in a nested configuration more easily and may allow easier access for a forklift truck.

Further preferably, at least one side of at least one tapered foot of the pallet is concave. This may allow nested pallets to be released more easily from their nested configuration.

Preferably, recesses are provided in the upper surface of the platform of the pallet. Further preferably, the recesses in the upper surface correspond to the position of the feet of a pallet element. Hence the feet of stacked pallet elements may fit into the recesses in the upper surface of the pallet element below.

In a preferred embodiment, at least one foot is hollow.

Preferably, the recesses in the upper surface extend through the platform from the upper surface of the pallet element into the feet.

Preferably, pallet elements form a nested configuration when stacked on top of each other in the same orientation.

Further preferably, in a nested configuration, the feet of one pallet element are inserted into recesses in the corresponding feet of a second pallet element. This may allow the pallets to stack together in a closely nested configuration and hence advantageously significantly reduce the volume taken up by unloaded pallets.

In a preferred embodiment, the feet are arranged to enable the blades of a forklift truck to engage the pallet from any one of four directions. In an alternative embodiment, in particular if the pallet is rectangular, it may be possible to lift the pallet from only two directions.

In a preferred embodiment, at least a portion of the pallet element comprises an outer skin layer.

Further preferably, at least a portion of the pallet element comprises an inner layer having a different composition to the outer skin layer.

Preferably, the inner layer comprises a foaming agent.

In one embodiment, the pallet element further comprises a remotely readable tag, preferably an RFID tag. The tag may be used to store and provide details of the load of the pallet or its location or ownership details.

In a preferred embodiment, the platform of the pallet element comprises a substantially continuous surface. This may allow small items to be carried on the pallet.

Preferably, the platform of the pallet element comprises a textured surface. This may increase the ability of objects to grip the surface of the pallet and reduce slippage during transportation.

A method of assembling a double-sided pallet using two pallet elements, each pallet element comprising a platform and a plurality of feet depending from the platform, the method comprising:

rotating the first pallet element about an axis in the plane of the pallet platform;

arranging the second pallet element on top of the first pallet element so that the feet of both of the pallet elements lie between the platforms of the pallet elements and the feet of the pallet elements are interleaved;
coupling the second pallet element to the first pallet element.

In a preferred embodiment, the step of coupling comprises applying pressure to the pallet elements.

Further preferably, applying pressure comprises applying a force of less than around 1000N, preferably less than around 500N, or applying an impact from a hammer of less than 10Ns.

Preferably, coupling comprises coupling the pallet elements without adhesives or fixings.

According to a further aspect, there is provided a method of manufacturing a plurality of pallets comprising:
inserting a feedstock comprising a filled plastics material into a mould;
rotating and heating the mould to rotationally mould a plurality of pallets;
releasing the plurality of pallets from the mould
separating the moulded plurality of pallets into single pallets.

In one embodiment, the method further comprises inserting a second feedstock into the mould to form an inner layer within the pallet.

Preferably, the second feedstock includes a foaming agent to form a foamed inner layer.

In one embodiment, separating the moulded plurality of pallets comprises punching or cutting the pallets out of a sheet of moulded pallets.

According to a further aspect, there is provided a method of distributing pallets comprising arranging layers of pallets in a nested configuration in a container, shipping the container to a predetermined destination, removing the pallets from the container.

Preferably, the pallets comprise pallet elements according to the aspect described above or any of its preferred features.

Preferably, the pallets and the container are rotationally moulded.

In one embodiment, the layers of pallets are provided in sheets and the method further comprises cutting the sheets of pallets into individual pallets.

According to one aspect there is provided a rotationally-moulded load-carrying apparatus for carrying a load of at least 50 kilograms, wherein the apparatus is manufactured substantially from a filled plastics material comprising:
at least 10% by weight of a polymer;
at least 10% by weight of a mineral filler material.

In some cases, up to 90% by weight of the remainder of the composition may comprise filler. However, a number of other components may be included in the composition. In particular, a component to unify the polymer and the filler may be provided, or a unifier may be present in the filler or polymer. Preferably at least 1% by weight and less than 20% by weight unifier is provided. Further components that may be incorporated in the material include a colourant, a flame retardant and a stabiliser, for example a UV stabiliser.

Manufacturing load-carrying apparatus using a plastics based material may provide a number of advantages, as set out in more detail below. However, it has been found that containers manufactured substantially from a purely plastics material are not sufficiently resilient to withstand the temperatures and stresses to which they may be subjected during normal use. The addition of a filler may solve this problem by increasing the strength and structural integrity of the apparatus.

Forming the apparatus from a plastics material may be advantageous since the unladen weight of the plastic apparatus may be less than that the equivalent prior art apparatus, which may be manufactured from materials such as steel or wood. This may allow a user to use the apparatus to carry a greater weight of goods, whilst keeping the gross weight constant, or may allow a transportation operator, for example a shipping merchant, to pack more load-carrying apparatus onto a ship or to save fuel in transportation of the apparatus.

In addition, apparatus manufactured from a plastics based material will not suffer from the problems associated with rusting and hence such apparatus may not require painting. These properties may enable the expected lifetime of the apparatus to be increased. For example, the expected lifetime of a prior art steel shipping container may be about 5 years for a steel container whereas a lifetime of about 25 years is reasonable for a plastics-based container. A further advantage may be that, when the plastic apparatus is brought out of operation, it may be broken up and ground and the material may be recycled to form parts of new apparatus.

A further advantage of such apparatus is that it may be possible to determine, verify or monitor the contents of the apparatus using a remote sensing technique, such as X-rays or thermo-sensing, since it may be possible for such radiation to pass through the material of the apparatus. This may allow authorities to ensure that the contents of the apparatus do not comprise a security risk and may allow authorities to detect illicit or undesirable goods or to verify that the contents of the apparatus correspond to the declared contents.

A further property of the apparatus may be that the plastics material has better insulating properties than the material used for the equivalent prior art apparatus, for example steel. This may allow the contents of the apparatus to be better insulated from high or low temperatures than in the prior art apparatus. This may enable, for example, refrigerated containers to be provided more easily and such containers may require less power to be maintained at a constant temperature.

Rotationally moulding the apparatus may allow the apparatus to be formed with few internal stresses in the material. This may lead to a stronger load-bearing apparatus than would be provided by other forms of moulding.

Preferably, the mineral material comprises a silicate or comprises a carbonate material. In a highly preferred embodiment, the filler comprises sand, preferably consists essentially of sand. The sand is preferably dredged sand. Sand is readily available at consistent granularity and can form a surprisingly effective filler. Another advantage of using sand as part of the filler material is that it may provide additional security for the container, since container walls that include sand may be difficult to cut through, since the sand in the composition is likely to blunt quickly any machinery that is used to attempt to cut through the material. In an alternative embodiment, the filler may comprise calcium carbonate.

Further, the filled material described herein is likely to be flame retardant, although a further flame retardant component may also be incorporated into the filled material.

In a preferred embodiment, the polymer comprises polyethylene. The polymer used may depend on the apparatus being manufactured and other polymers, such as PVC or PVA may be used. However, polyethylene may provide a hard-wearing, resistant material for use in a wide range of apparatus.

More preferably, the polymer comprises High Density Polyethylene (HDPE).
Preferably, the material comprises at least 25% by weight filler.

Preferably, the material comprises at least 25% by weight polymer.

In a highly preferred embodiment, the material comprises from about 30% to about 70% by weight polymer and from about 70% to about 30% by weight filler. The polymer and the filler may comprise 100% of the material or other components may be included in the material as described herein and the additional components may comprise the remaining % weight of the material.

In a preferred embodiment, the filled plastics material further comprises a unifier. The unifier may be provided to bind the polymer and the filler together.

Preferably, the filled plastics material comprises at least about 0.1% by weight unifier. Preferably, the filled plastics material comprises less than about 10% by weight unifier.

More preferably, the filled plastics material comprises at least about 0.25% by weight unifier. More preferably, the filled plastics material comprises less than about 5% by weight unifier.

In a preferred embodiment, the unifier is pre-mixed with the filler before the filler is mixed with the polymer.

In one embodiment, the unifier may comprise an internal lubricant. Alternatively or additionally, the unifier may comprise an external lubricant. The internal lubricant may act to improve lubrication between the polymer chains.

In a preferred embodiment, the internal lubricant comprises a fatty acid amide. More preferably, the internal lubricant comprises a straight or branched C_{12}-C_{24} fatty acid amide. More preferably, the internal lubricant comprises steramide.

In a preferred embodiment, the external lubricant comprises a stearate.

Preferably, the unifier comprises less than 20% by weight internal lubricant. More preferably, the unifier comprises about 10% by weight internal lubricant.

Preferably, the filler comprises at least one of:

a silicate material, preferably sand;

ash;

a carbonate material, preferably calcium carbonate;

a salt, preferably sodium chloride.

The filler may comprise a mixture of filler materials. Preferably, the filler material is inert, more preferably the filler material is inorganic, although organic fillers, such as wood flour, peanut hulls, ground straw or animal litter may be used. Preferably, the filler is provided or is ground into small particles, since this may provide a more uniform material. Dredged sand may be used in preference to desert sand since the particles of dredged sand are finer than those of desert sand.

In a preferred embodiment, the apparatus is rotationally moulded substantially in one piece. Moulding the apparatus substantially in one piece may advantageously allow the product to be produced without substantial post-processing of the moulded product. Parts of the apparatus (for example, the doors of a container) may be moulded separately and coupled to the apparatus after the main moulding process.

In one embodiment, the apparatus comprises a freight container. A freight container manufactured as described herein may provide the advantages outlined above. In particular, the plastics container may be lighter and may be more durable and more environmentally sustainable than a prior art steel container. In addition, it may be possible to X-ray or obtain a thermal image of the plastics container to determine its contents and increase security.

In one embodiment the freight container comprises an elongate freight container having a length of at least 5m, e.g. e.g. the container may comprise a 20 foot (about 6m) container.

In a further embodiment, the freight container may comprise an elongate freight container having a length of at least 10m, e.g. the container may comprise a 40 foot (about 12m) high-cube container. This may allow the container to be used in the same way as an existing steel container that meets the standards for a 40' high cube container. For example, the plastics 40' container may be stacked with prior art containers and may be transported using the same apparatus and fixing means as a prior art container, for example the container may be fixed onto a transport lorry in the same way as a prior art container. As will be appreciated by one skilled in the art, however, the container may comprise storage and transportation apparatus of any shape or size.

Preferably, the thickness of the walls of the container is less than about 90mm. Hence the container may have thinner walls than a prior art steel container. In one embodiment, the walls may have a thickness of about 70mm.

Preferably, the filler comprises a light-coloured material. This may enable the apparatus to be manufactured in a light colour without requiring painting or expensive pigments. For a container,

manufacturing the container in a light colour may help the container to maintain a lower temperature when it is exposed to high temperatures, particularly to radiated heat such as intense sunlight.

In one embodiment, the apparatus comprises a pallet. A plastics-based pallet may advantageously provide an alternative to the prior art wooden pallets. The plastic pallet may have a longer usable life than a wooden pallet, since the plastic pallet may be stronger and more durable that a wooden pallet. Hence the plastic pallet may be more environmentally sustainable than a wooden pallet.

Preferably, the pallet is moulded substantially in one piece. Preferably, a plurality of pallets may be moulded in a single moulding operation.

Preferably, the pallet comprises a platform and a plurality of feet depending from the platform.

More preferably, the feet are arranged to enable lifting equipment to engage the pallet from any one of four directions. Hence the pallet may be a four-way-access pallet, which may be lifted from any one of four directions, for example by a fork-lift truck.

Preferably, the feet of the pallet are regularly spaced over the lower surface of the platform. Bracing members may be provided between the feet of the pallet.

Preferably, at least one foot is arranged substantially at each corner of the platform of the pallet. Hence, each corner of the platform may be supported.

More preferably, at least one foot is arranged substantially at the centre of the platform of the pallet. This may further strengthen the platform pallet at the centre.

Preferably, at least one foot is arranged substantially at the centre of each edge of the platform of the pallet. Hence a total of 9 feet are preferably provided for each pallet. Four feet may be provided at the corners of the pallet, a further four feet may be provided at the centre of each edge of the pallet and a further, 9th foot may be provided under the centre of the platform of the pallet.

In a preferred embodiment, each foot has a recess in the lower surface of the foot. This may advantageously reduce the weight of the pallet, without reducing the strength of the pallet. In addition, the pallet may be formed without requiring a large cavity in each foot to be evenly filled with an inner layer.

Preferably, the pallet comprises an outer skin layer having an upper surface and a lower surface.

More preferably, the upper and lower surfaces of the outer skin layer are arranged to abut each other over at least a portion of the pallet surface. In one embodiment, the upper and lower surfaces may form a cavity over the feet of the pallet but may abut each other, e.g. the surfaces may be formed substantially without a gap between them, over the platform areas of the pallet. The outer skin layer may be the only layer of the pallet and the cavities formed between the upper and lower surfaces may be filled with air. Alternatively, the cavities may be filled with a further material, such as a foamed plastics material or a filled plastics material.

In a preferred embodiment, the pallet further comprises an inner layer having a different composition to the outer skin layer. Providing an inner layer within the outer skin may add further strength and rigidity to the pallet.

Preferably, the inner layer comprises a foaming agent. Providing the layer as a foam layer may ensure that the additional layer does not add significantly to the overall weight of the pallet.

In an alternative embodiment, the inner layer comprises at least 40% by weight of a filler. Using a highly filled inner layer may enable the pallet to be strengthened, but the highly-filled layer may be inexpensive.

In a preferred embodiment, the feet of the pallet are moulded integrally with the platform.

Preferably, the pallet has a length of at least 800mm. In one embodiment, the pallet may have dimensions corresponding to those of a standard pallet, that is about 1020x1220x120mm (40x48x5 inches).

Preferably, the feet of the pallet have a width greater than about 30mm.

In a further embodiment, the apparatus comprises a cable reel.

In a highly preferred embodiment, the apparatus comprises a plurality of layers.

Preferably, the composition of the filled plastics material differs between the layers. This may allow properties of a plurality of compositions to be incorporated into the apparatus.

Preferably, the composition of a first layer of the apparatus is optimised to provide an outer skin layer. Preferably, the outer skin layer is manufactured to be durable enough to withstand the conditions and the chemicals to which the apparatus may be subjected during normal use.

Preferably, the outer skin layer comprises more than about 20% by weight filler. More preferably, the outer skin layer comprises less than about 80% by weight filler. This may ensure that the outer skin layer is not too brittle.

Preferably, the outer skin layer comprises more than about 50% by weight polymer, more preferably, the outer skin layer comprises about 60% by weight polymer.

In a preferred embodiment, the composition of a second layer of the apparatus is optimised to provide an inner layer. The inner layer may be formed within the outer skin layer and may comprise a highly-filled or a light-weight layer.

In a preferred embodiment, the inner layer comprises a polymer. Hence the inner layer may not contain a filler material. This may be advantageous since a polymer, particularly a foamed polymer, may be lighter than a filled polymer.

In an alternative embodiment, the inner layer comprises a polymer and a filler.

In one embodiment, the inner layer comprises more than about 30% by weight filler. A highly-filled inner layer may be provided, since it will be protected by the outer skin layer. Hence the inner foam layer may have different surface properties to the outer skin layer, since it will not be subjected to external conditions. A highly filled, relatively dense, inner layer may be provided inexpensively, for example using a low-grade filler.

More preferably, the inner layer comprises more than about 50% by weight filler. In a preferred embodiment, the inner layer comprises about 60% by weight filler.

In a preferred embodiment, the inner layer comprises a greater amount of filler by weight than the outer layer.

In a highly preferred embodiment, the inner layer comprises a foaming agent, preferably the foam layer is about 50% foamed. This may mean that the inner layer is a light layer and does not increase significantly the overall weight of the apparatus.

In some embodiments, the filled plastics material further comprises a pigment. Advantageously, the apparatus may be coloured to any colour required simply by adding a pigment to the feedstock. This may allow apparatus of a consistent colour to be produced without requiring the further step of painting the apparatus. In some embodiments, the product formed from the material, for example the container or the pallet, may further be printed on.

In a preferred embodiment, the apparatus incorporates a remotely readable Identification (ID) tag, preferably an RFID tag. The tag may be used to store information about the container and/or the contents of the container. For example, details of the contents of the container, its source, its destination, and the owner of the contents of the container may be recorded.

Preferably, the ID tag is moulded into the surface of the apparatus.

In some embodiments, the filled plastics material further comprises a stabiliser, preferably a UV stabiliser. This may allow the material to be exposed to Ultra-Violet radiation, for example sunlight, without degrading the plastics material.

In some embodiments, the filled plastics material further comprises a plasticizer.

According to a further aspect, there is provided apparatus for sealing a freight container comprising sealing means manufactured from a plastics material, wherein the plastics material is soluble in salt-water.

A problem in the container freight shipping industry is that containers are often lost overboard from container ships. The lost containers often contain air and other matter less dense than water and, since the containers are substantially air-tight, the containers may float on or just below the surface of the water. This may cause a hazard for other shipping in the area. The aspect described above may therefore allow a container lost overboard to lose its seal, to fill with water and to sink, which may reduce or remove the potential hazard caused by the container.

Preferably, the plastics material comprises PVA or PVOH.

Preferably, the plastics material further comprises a filler and/or a unifier.

Preferably, the seal is arranged to dissolve in salt water over a period of about 5 days.

According to a further aspect, there is provided a method of manufacturing apparatus for storage or transportation of loads greater than about 50 kilograms, the method comprising rotationally moulding the apparatus from a filled plastics material comprising a polymer, a filler and a unifier.

According to a further aspect, there is provided X-ray apparatus for forming an X-ray of the contents of a load-carrying apparatus for carrying loads of at least 50 kilograms and manufactured from a filled plastics material, comprising:
a scanning area;
energy delivery means for providing energy of a suitable frequency spectrum and intensity to penetrate at least 20mm of the filled plastics material;
energy detecting means to detect reflected energy.

According to a further aspect, there is provided thermal imaging apparatus for forming a thermal image of the contents of a load-carrying apparatus for carrying loads of at least 50 kilograms and manufactured from a filled plastics material, comprising:
a scanning area;
energy detection means for detecting thermal energy transmitted from within the load-carrying apparatus.

Preferably, the scanning area has a maximum dimension of at least 1m. In one embodiment, the scanning area has a maximum dimension of at least 2m.

Preferably, the filled plastics material comprises at least 10% by weight of a mineral filler, preferably a silicate or a carbonate filler.

In one embodiment, the load-carrying apparatus comprises a freight container. Hence the contents of containers may be determined using the imaging apparatus.

In one embodiment, the load-carrying apparatus has a length of at least 5m. In a further embodiment, the load-carrying apparatus has a length of at least 10m.

A further aspect provides a method of rotationally moulding a product from a filled plastics material comprising:
providing a mould for the product defining a void corresponding to at least a portion of the required shape of the product;
loading a first feedstock having a first composition comprising a polymer and at least 10% by weight of a mineral filler into the mould;

heating the mould;

rotating and/or rocking the mould about at least two axes to coat the internal walls of the mould with a layer of the first feedstock;

cooling the mould;

releasing the product from the mould.

The method described above may advantageously provide an efficient method of rotationally moulding products.

Preferably the method further comprises providing heating means adjacent to the walls of the mould and heating the mould using the heating means. Applying heat using heating means adjacent to the walls, such as one or more burners, for example gas or oil burners, or one or more electric heated plates, may allow the mould to be heated evenly over its whole surface without requiring the mould to be placed in and rotated within an oven. Hence the mould may be heated more quickly, since it is not necessary to heat a whole oven and the energy-efficiency of the process may also be increased.

Preferably, the method comprises providing cooling means adjacent to the walls of the mould and cooling the mould using the cooling means. Similarly, providing cooling means adjacent to the walls, such as a stream or jet of water or cooled air, may increase the energy efficiency and decrease the moulding time for the product, since the mould may be cooled directly, without requiring a moulding oven to be cooled.

In addition, using heating and cooling means adjacent to the mould walls may allow moulds of any size or shape to be used without the user requiring a moulding oven of a corresponding size.

Preferably, the heating means comprise a plurality of burners. Preferably, the burners comprise gas or oil burners.

Preferably, the cooling means comprises at least one supply of water, for example, a stream, a pool or a jet of water.

Preferably, the mould is a generally elongate mould and the method comprises rotating the mould about a first axis substantially parallel to the axis of elongation of the mould and rocking the mould about a second axis substantially orthogonal to the first axis.

In a preferred embodiment, rocking the mould comprises rocking the mould through a portion of a circle to a maximum angle from the horizontal of less than about 30°. Preferably, the mould is rocked

to a maximum angle from the horizontal of about 15°. In some embodiments, particularly if the mould is a small mould, the mould may be rocked to an angle greater than about 30°, for example the mould may be rocked to about 45°.

Preferably the mould is rocked at a rate of less than about 6 rocking cycles per minute. Preferably, the mould is rocked at a rate of about 4 cycles per minute.

Preferably, the mould is rocked at a rate of greater than about 1 rocking cycle per minute.

Preferably rotating the mould comprises rotating the mould at a rate of less than about 10 revolutions per minute. More preferably around 4 revolutions per minute. Preferably, rotating the mould comprises rotating the mould through 360°. Alternatively, the mould may not be rotated through a full circle. The mould may be constantly rotated in the same direction, or the direction of rotation may be reversed periodically.

In some embodiments, particularly if the mould is a small mould, the mould may be rocked and/or rotated at a faster rate. However, except for small moulds, the cycle rate is likely to be less than about 30rpm.

Using a rotation or rocking rate that is too slow may lead to an uneven distribution of feedstock within the mould, since gravitational effects may dominate the motion of the feedstock. However, using a rotation or rocking rate that is too fast may not be energy-efficient and centrifugal effects may also lead to an inferior product.

Hence it is preferably not necessary to rotate or to rock the mould at a high rate. The rotating and rocking of the mould is preferably a continuous motion, but may not be continuous in some embodiments.

In a preferred embodiment, the mould comprises an inner mould portion and an outer mould portion, wherein the inner mould portion is positioned within the outer mould portion and wherein the first feedstock is inserted between the outer mould portion and the inner mould portion. Hence the product may be formed between the two moulds. This may allow the inner surface of the product to be provided with a predetermined shape and may allow the thickness of the product to be controlled. The feedstock is preferably inserted between the moulds and the moulds are heated and rotated together to ensure that the melted feedstock covers the surfaces of both of the moulds.

Preferably, the method further comprises providing heating means within the inner mould portion. Hence the inner mould portion may be heated to provide a more even temperature distribution throughout the moulding volume.

Preferably, the method further comprises maintaining the heating means at a substantially constant distance from the walls of the outer mould portion as the mould is rotated. This may enable all parts of the mould to be heated evenly and hence may encourage a more even distribution of the plastics material within the mould.

Preferably, the method further comprises, before cooling the mould:
loading a second feedstock, having a second composition, into the mould;
rotating the mould to form a second layer of the second feedstock.

Preferably, the composition of the first layer is optimised to provide an outer skin layer.

Preferably, the composition of the second layer is optimised to provide an inner layer.

In a preferred embodiment, the second feedstock comprises a foaming agent. Preferably, the second feedstock becomes foamed after insertion into the mould on the application of heat to the mould. Hence the feedstock may be distributed evenly within the mould before being foamed. Aeration of the feedstock may release nitrogen or another similar, preferably substantially inert gas. Preferably, a foaming agent, such as sodium bicarbonate, may be incorporated into the second feedstock.

Preferably, the second feedstock comprises a higher proportion of filler than the first feedstock. In one embodiment, the second feedstock comprises at least 50% by weight of a mineral filler. However, as described for the pallet above, the second feedstock may not contain a filler but may simply be a polymer, preferably a foamed polymer. Alternatively, the second feedstock may be highly filled.

The mineral filler preferably comprises a silicate filler, such as sand, or a carbonate filler, such as calcium carbonate.

In one embodiment, the product may comprise at least one of: a freight container, a pallet, a cable reel or a panel. Preferably, a plurality of products are produced in a single moulding operation.

In one embodiment, the method may further comprise positioning elements of the product within the mould before the feedstock is inserted and over-moulding the elements into the product. This may

further reduce the amount of post-processing required for the product and ensure that the additional components are securely fixed into the product.

In one embodiment, the product comprises a freight container and the elements comprise one or more of:

a metal frame;
door securing means;
strengthening elements; or
corner lifting elements.

In a highly preferred embodiment, the product is moulded substantially in one piece.

Preferably, releasing the product from the outer mould portion comprises moving the walls of the outer mould portion apart and away from the moulded product. Hence the outer mould portion may be removed from the moulded product and the product may be removed from the inner mould portion. This may advantageously allow the product to be formed with shaper and more well-defined edges, since prior art moulding techniques have previously required the product to be removed from a tightly-fitting mould, so it has been necessary to form products with rounded edges to allow the product to be removed from the mould more easily.

A further aspect may provide a filled plastics material comprising:

a polymer;
at least 10% by weight of a mineral filler;
a unifier comprising stearate.

Preferably, the unifier further comprises an internal lubricant, preferably steramide.

More preferably, the steramide comprises Chrodamide S Powder.

Preferably, the stearate comprises Calcium Stearate.

Preferably, the unifier comprises more than 5% by weight steramide. More preferably, the unifier comprises about 10% by weight steramide.

Preferably, the unifier comprises more than 80% by weight stearate. More preferably, the unifier comprises about 90% by weight stearate.

In a preferred embodiment, the polymer comprises polyethylene. More preferably, the polymer comprises High Density Polyethylene (HDPE).

Preferably, the filler comprises at least one of:
a silicate material, preferably sand;
ash;
a carbonate material, preferably calcium carbonate;
a salt, preferably sodium chloride.

A mixture of filler materials may be used, as described above.

Preferably, the filled plastics material comprises at least 0.1% by weight unifier. More preferably, the filled plastics material comprises about 1% by weight unifier.

According to a further embodiment, there is provided apparatus for rotationally moulding, from a filled plastics material, a load-carrying apparatus for carrying a load of at least 50 kilograms, the apparatus comprising:
a mould defining a void corresponding to at least a portion of the required shape of the product;
means for receiving a first feedstock comprising a filled plastics material comprising a polymer and at least 10% by weight of a mineral filler;
heating means;
cooling means;
means for rotating and/or rocking the mould about at least two axes.

Preferably, the heating means are provided adjacent to the walls of the mould.

Preferably, the cooling means are provided adjacent to the walls of the mould.

In a preferred embodiment, the mould is a generally elongate mould and the apparatus further comprises means for rotating the mould about a first axis substantially parallel to the axis of elongation of the mould and means for rocking the mould about a second axis substantially orthogonal to the first axis.

Preferably, the mould comprises an inner mould portion and an outer mould portion, wherein the inner mould portion is positioned within the outer mould portion and wherein the first feedstock is inserted between the outer mould portion and the inner mould portion.

Preferably, the apparatus further comprises heating means within the mould, preferably within the inner mould portion.

In a preferred embodiment, the apparatus further comprises means for maintaining the heating means at a substantially constant distance from the mould.

In one embodiment, the outer mould portion has a length of at least 5m. Preferably, the outer mould portion has a length of at least 10m.

Preferably, the filled plastics material comprises at least 30% by weight of a mineral filler. Preferably, the filler comprises a silicate or a carbonate material.

Preferably, the apparatus is mounted over a pit and wherein at least one end of the outer mould portion is rocked into the pit.

Preferably, the means for receiving the feedstock comprises a series of apertures in the outer mould portion. Using a plurality of apertures may allow the feedstock to be inserted into the mould at a high rate. This may decrease the moulding cycle time and may reduce the amount of energy used in each moulding cycle. The feedstock may also be distributed more evenly throughout the mould. Using a series of apertures may be particularly advantageous when the second and any subsequent feedstocks are inserted, since the second feedstock may be inserted quickly an evenly within the first feedstock.

Preferably, the series of apertures is formed along at least one edge of the outer mould portion.

More preferably, the series of apertures is covered by at least one sliding gate valve.

According to a highly preferable embodiment, the internal surface of the sliding gate valve is coated in a non-stick material. This may allow a second or subsequent feedstock to be inserted within a first moulded feedstock. For example, an inner layer of a product may be inserted within an outer shell layer. This may be achieved since the first feedstock preferably does not adhere to the non-stick material, so an aperture in the feedstock layer may be provided when the gate is opened to allow the second feedstock to be inserted.

In a preferred embodiment, the apparatus comprises at least one hopper for storing the feedstock. Preferably, the hopper comprises dispensing means for dispensing a predetermined amount of the feedstock, wherein the predetermined amount comprises the amount of feedstock required to rotationally mould at least one load-carrying apparatus.

Preferably, the apparatus further comprises filling means for loading the mould with a predetermined amount of the feedstock.

Preferably, the filling means comprises means for filling the feedstock via a series of apertures in the outer mould portion.

Preferably the means for filling the feedstock comprises at least one bucket having a series of apertures corresponding to the series of apertures in the outer mould portion.

More preferably, the bucket comprises a telescopic bucket having an adjustable length. This may enable the bucket to be transported to the moulding apparatus more easily.

In a preferred embodiment, the heating means comprises at least one gas burner.

Preferably, the cooling means comprises a jet of water. The water may be cycled through a cooling system or may be provided from a reservoir, for example from the sea.

According to a further aspect, there is provided a unifier for promoting binding and dispersion of a mineral filler and a polymer, wherein the unifier comprises a fatty acid amide.

Preferably, the fatty acid amide comprises a straight or branched C_{12}-C_{24} fatty acid amide. More preferably, the unifier comprises steramide.

In a preferred embodiment, the unifier further comprises an external lubricant, preferably wherein the external lubricant comprises a stearate.

Preferably, the unifier comprises more than 80% by weight external lubricant. More preferably, the unifier comprises about 90% by weight external lubricant.

Preferably, the mineral filler comprises a silicate or a carbonate material, more preferably the filler comprises sand or calcium carbonate.

According to a further aspect, there is provided a rotationally-moulded load-carrying apparatus comprising:

at least 10% by weight HDPE;

at least 10% by weight of a filler comprising sand;

a unifier comprising a fatty acid amide;
wherein the load-carrying apparatus comprises an inner layer and an outer layer, the layers having different compositions.

In one embodiment, the apparatus comprises an elongate container having a length of at least about 5m and a wall thickness of at least about 40mm.

In one embodiment, the apparatus comprises a pallet having a length of at least about 800mm.

Preferably, the inner layer comprises a foamed layer.

According to a further aspect, there is provided a pallet made of a plastics material capable of meeting, or exceeding, any, some or all of the test criteria described herein.

According to a further aspect, there is provided a rotationally moulded pallet manufactured substantially from a filled plastics material, wherein the pallet has:
a length of greater than around 1000mm and less than around 1500mm;
a mass of less than around 30kg;
a maximum load carrying capability of greater than around 1000kg.

Preferably, the mass of the pallet is less than around 25kg, preferably around 23kg.

Preferably, the maximum load carrying capability of the pallet is greater than around 1100kg, preferably around 1250kg.

Preferably, the pallet further comprises an ultraviolet stabiliser. Preferably, the pallet has an opaque and/or a non-reflective surface.

In a preferred embodiment, the pallet comprises a top deck, a bottom deck, and at least one spacer positioned between the top deck and the bottom deck.

Preferably, the top of the top deck, the top of the bottom deck and the interior of the at least one spacer are surface textured to around 15μm to 20μm.

In one embodiment, the pallet further comprises an indelible marking. Preferably; the pallet is marked with a code.

In a preferred embodiment, the pallet comprises recyclable materials.

Preferably, the pallet has a damage rate per trip of less than or equal to 0.25%.

Preferably, the pallet does not contain sufficient amounts of residual monomers, residual solvents or other volatile substances to contaminate products under load.

In a preferred embodiment, the pallet is compatible with fat-containing foods. Preferably, the pallet does not emit or absorb noxious or toxic substances, or strong odours. Preferably, the pallet comprises a material which is non-porous and non-hydroscopic.

In a preferred embodiment, the pallet has anti-static properties. Preferably, the pallet is designed to allow circulation of air through the pallet.

In one embodiment, the pallet comprises a top deck and the top deck comprises through holes which are tapered so that the smaller openings are at the top of the top deck and the larger openings are at the bottom of the top deck.

In one embodiment, the pallet comprises a top deck and a bottom deck and all of the internal radii on the bottom of the top deck and the bottom of the bottom deck have a minimum radius of approximately 3.175 mm.

In one embodiment, the pallet comprises a top deck and a bottom deck and the pallet has a minimum slope of approximately 3° across the top of the bottom deck.

In a preferred embodiment, the pallet, after being rinsed with water at 22°C ±2°C and allowed to air-dry at 22°C ±2°C, retains no more than approximately 20g of water.

Preferably the pallet comprises a means of identification. Further preferably, the means of identification comprises a RFID tag or a barcode.

In one embodiment, the pallet further comprises a lug suitable for securing a stretchwrap leader to.

Preferably, the pallet has a bottom deck coverage of more than 55%.

Embodiments of the invention will now be described with reference to the drawings in which:

Fig. 1 illustrates a container and moulding apparatus according to one embodiment;

Figs. 2a and 2b are schematic diagrams of a further embodiment of a moulded container and moulding apparatus according to one embodiment;

Fig. 3 is a schematic diagram of a further embodiment of a moulded container and moulding apparatus according to one embodiment;

Fig. 4 illustrates a further embodiment of moulding apparatus according to one embodiment;

Fig. 5 is a schematic diagram of a container according to one embodiment;

Fig. 6 illustrates one embodiment of a container manufactured according to the methods and apparatus described herein;

Fig. 7 is a schematic diagram of a reinforcing eyelet according to one embodiment;

Fig. 8 is a schematic diagram of a reinforcing eyelet moulded into a container according to one embodiment;

Fig. 9a is a schematic perspective view of the top of one embodiment of a pallet manufactured according to the methods and apparatus described herein;

Fig. 9b is a schematic perspective view of the bottom of one embodiment of a pallet manufactured according to the methods and apparatus described herein;

Fig. 10 is a schematic diagram of a pallet according to one embodiment;

Fig. 11 is a schematic diagram of a manufacturing plant for implementing the methods described herein;

Fig. 12 is a further schematic diagram of a manufacturing plant for implementing the methods described herein;

Fig. 13 is a schematic diagram illustrating the loading of feedstock into a moulding apparatus according to one embodiment;

Fig. 14 illustrates example moulding cycle times for a plastics-based filled compared to polyethylene;

Fig. 15 illustrates example impact strengths for a plastics-based filled compared to polyethylene;

Fig. 16 illustrates example tensile modulus results for a plastics-based filled material compared to polyethylene;

Fig. 17 illustrates one embodiment of a pallet element;

Fig. 18 illustrates a plurality of identical pallet elements stacked in different configurations;

Fig. 19 further illustrates a plurality of stacked, identical pallet element;

Fig. 20 illustrates a close-up view of the feet of three stacked pallet elements according to one embodiment;

Fig. 21 is a schematic diagram illustrating how a plurality of pallets may be moulded in a single mould;

Fig. 22 illustrates a portion of a mould that may be used in the manufacture of pallets according to one embodiment;

Fig. 23 illustrates a section of the mould of Fig. 22 in more detail;

Fig. 24 illustrates two pallets according to an alternative embodiment;

Fig. 25 is a schematic diagram of a cross-section through part of a mould for a pallet;

Fig. 26 is a schematic diagram of a cross-section through a part of a mould for a pallet;

Fig. 27 is a schematic diagram of a plan view of part of a mould for a pallet;

Fig. 28 is a schematic illustration of a typical test pallet;

Fig. 29 is a schematic diagram of a flow chart for determining sample size for static load tests and slip resistance tests;

Fig. 30 is a schematic diagram of layer A (Fig. 29a) and layer B (Fig 29b) of a uniform granular load;

Fig. 31 is a set-up schematic for a pallet spacer (block) compression (creep) test;

Fig. 32 illustrates a standard load applicator for a pallet spacer lateral compression test;

Fig. 33 is a set-up schematic for a pallet spacer lateral compression test;

Fig. 34 is a set-up schematic for an edge rack support (creep) test;

Fig. 35 is a set-up schematic for a short span support (creep) test;

Fig. 36 is a set-up schematic for a fork tine support test;

Fig. 37 is a set-up schematic for a stacked load support - top deck (creep) test;

Fig. 38 is a set-up schematic for a stacked load support - bottom deck (creep) test;

Fig. 39 is a set-up schematic for a conveyor support (line load) (creep) test;

Fig. 40 is a schematic diagram of a load cycle definition for a re-creep test;

Fig. 41 is a set-up schematic for a load cycling (re-creep) test;

Fig. 42 is a set-up schematic for a deck separation test;

Fig. 43 is a set-up schematic for a non-plastic load-on-pallet slip resistance test;

Fig. 44 is a set-up schematic for a buckling test; and

Fig. 45 illustrates the standard fork for inclined impact tests;

Fig. 46 is a side view of a top pallet element according to a further embodiment;

Fig. 47 is a perspective view of the under-side of a top pallet element according to one embodiment;

Fig. 48 is a perspective view of the top-side of a top pallet element according to one embodiment;

Fig. 49 is a plan view of the top of a bottom pallet element according to one embodiment;

Fig. 50 is a perspective view of the under-side of a bottom pallet element according to one embodiment;

Fig. 51 is a side view of a bottom pallet element according to one embodiment;

Fig. 52 is a perspective view of the under-side of a pallet comprising connected top and bottom pallet elements according to one embodiment;

Fig. 53 is a perspective view of the top-side of a pallet comprising connected top and bottom pallet elements according to one embodiment;

Fig. 54 is a further perspective view of the top-side of a pallet comprising connected top and bottom pallet elements according to one embodiment;

Fig. 55 is a plan view of the under-side of a pallet comprising connected top and bottom pallet elements according to one embodiment;

Fig. 56 is a side view of a plurality of stacked pallet elements according to one embodiment;

Fig. 57 is a perspective view of a plurality of stacked pallet elements;

Fig. 58 illustrates a plurality of stacked pallet elements being transported on a fork lift truck.

A wide variety of shapes and sizes of pallets may be formed using the methods described herein and the forms of some embodiments of pallets will now be described in more detail with reference to Figs. 17 to 27.

Fig. 17 illustrates one embodiment of a pallet that may be manufactured according to the techniques described herein. The pallet has a substantially rectangular upper surface or platform 1710 and a plurality of feet 1712 depending from the surface.

The feet 1712 may be moulded integrally with the platform 1710 of the pallet, which may allow the feet to be coupled securely to the pallet and reduce the complexity of the manufacturing process when compared to the process of forming the feet separately and attaching the feet to the platform of the pallet.

In the present embodiment, the pallet includes a foot assembly at each corner of the pallet 1714, an assembly at the centre of the pallet and an assembly in the centre of each edge of the pallet. Each foot assembly may comprise one or more feet depending from the pallet surface.

The feet of the pallet are preferably arranged so that the pallet may be accessed by lifting and manoeuvring equipment from any of its four sides, in particular, so that the blades of a forklift truck can fit underneath the pallet from any side or from at least two sides.

The feet of the pallet are preferably tapered from a widest point at the platform of the pallet. This may increase the ease of access for lifting equipment to fit between the feet of the pallet and may also make it easier to connect the pallet to another pallet, as described in more detail below, to form a double-sided pallet assembly.

The upper surface of the platform of the pallet 1710 is preferably provided with an uneven surface, which may increase the grip of the surface for objects placed on the surface. The platform of the pallet is preferably a substantially continuous surface, although holes may be provided in the surface to reduce the net weight of the pallets. Providing a pallet with a substantially continuous surface may allow small objects to be carried on the pallets.

The feet of the pallet are preferably at least partially hollow. This may reduce the weight of each pallet without significantly reducing the pallet strength and hence may allow more goods to be loaded onto the pallet for a given gross weight. A hollow may be formed from the under-side of the feet or, as shown in Fig. 17, the hollow 1716 may be formed into the feet from the platform of the pallet. This may be advantageous in allowing the pallets to be stacked and nested, as described in more detail below.

The feet of the pallet are preferably arranged so that the pallet can be stacked with other pallets in a number of different configurations. For example, as shown in Fig. 18, the feet may be arranged so that the feet of a first pallet 1810, sitting directly on top of a second pallet, fit into the recesses 1812 in the platform of the second pallet. This may allow the pallets to be stacked in a secure and stable configuration. If the recesses in the feet are large recesses or hollows, then the unladen pallets may be stacked closely together in a nested configuration and the storage space required for unladen pallets may be reduced significantly.

The feet of the pallet may be arranged to be rotationally symmetrical so that the feet of a pallet fit into the recesses in the feet of a lower pallet even when one of the pallets is rotated through 180 degrees in an axis perpendicular to the plane of the platform.

If the feet are not arranged in a symmetrical configuration, as shown in Fig. 18, unladen pallets may be stacked without the feet of an upper pallet fitting into the recesses in the feet of a lower pallet by turning one of the pallets through 180 degrees. This may be advantageous since it may be easier for a forklift truck operator to manoeuvre the pallets if the pallets are not closely nested together. This feature may also give the user the options of nesting or not nesting stacked pallets.

As also illustrated in Fig. 18 and Fig. 19, a pallet may be combined with a second pallet to form a double pallet 1814, 1910. A double pallet may be formed by rotating one pallet through 180 degrees around an axis in the plane of the pallet and placing a second pallet over the inverted pallet so that both sets of feet of the two pallets lie between the pallet platforms. As illustrated in Figs. 18 and 19, the feet of the pallets 1912, 1914 are preferably arranged so that, when one pallet is inverted, the feet of the two pallets interleave so that each foot of both pallets touches the underside of the platform of the other pallet. Such a combination of pallets may be stronger and more rigid than a single pallet. A double pallet may be used to manoeuvre heavier loads or for more heavy-duty work.

As will be appreciated, a variety of arrangements of the feet of the platform may be provided to allow the feet of two platforms to interleave on formation of a double-sided pallet. The feet of the pallet are

preferably arranged asymmetrically in at least one axis of rotation in the plane of the pallet. Arranging the feet asymmetrically in only one axis of rotation means that the feet of pallets only interleave to form a double-sided pallet in one orientation, but may allow greater flexibility in the arrangement of feet on the pallets and hence may provide a more robust pallet when it is used in the single-sided formation.

One or more feet may be arranged at each corner of the pallet, at the centre of the pallet and along the edges of the pallet and, at each point, the one or more feet may have a male or a female configuration. The arrangement of the feet is preferably such that, in the double-sided formation, feet with a male configuration correspond to opposing feet with a female configuration and hence fit together. As illustrated in Fig. 19, a male configuration of feet may comprise a single foot 1916 and a female configuration of feet may comprise two feet 1918 with a gap in between sufficient to allow the foot of the opposing pallet to interleave between them. Other feet of the pallet, such as those shown along the centre line 1920 in Fig. 19, may be offset from the centre line or from the edge of the pallet. This may allow the feet of the pallet to interleave on formation of a double-sided pallet.

As illustrated in Fig. 20, the inner surfaces of the platform of each pallet may be provided with recesses 2010 corresponding to the position of the feet of the opposing pallet. This may reduce the likelihood of the two pallets moving or sliding relative to each other when they are in the double-pallet configuration. The recesses may allow the two pallets to be secured together, for example by allowing the feet of one pallet 2012 to 'clip' into the recess in the opposing pallet 2010. The recesses in the pallet platform may be provided with deformable teeth 2014 or prongs that fit tightly around the feet of the upper pallet to hold the pallets together. In some embodiments, the feet may also be provided with corresponding teeth to grip the edges of the recess in the platform.

Alternatively, a separate 'clip' mechanism may be provided to secure the two pallets together into the double pallet configuration. Inserting the feet of one pallet into recesses in the opposing pallet also allows the height of a double-sided pallet to be roughly equal to the height of a single-sided pallet.

Preferably, the two pallet elements may be joined without an adhesive or fixing mechanism simply by applying pressure to the elements. The pressure necessary to join the pallet elements is preferably not so large that a machine is required to join the elements. For example, the pressure required is preferably similar to the pressure exerted by a person standing on the pallet (for example 500-1000N) or the impact provided by a hammer (for example a hammer of around 2kg may provide an impact of around 10Ns), however, the pallets may be designed to be joined using a smaller or a larger required pressure.

In an alternative embodiment, the feet of the pallet may be formed with prongs 2410 and corresponding slots 2412, as illustrated schematically in Fig. 24. On rotation of one of the pallets, the prongs of one set of feet may engage with the corresponding slots of the other set of feet to form a double-sided pallet.

Embodiments of the pallet are preferably manufactured using the rotational moulding techniques described herein. Each pallet may be moulded individually but, preferably, a large number of pallets are moulded in a single rotational moulding operation.

Fig. 21 illustrates how a plurality of pallets 2110 may be moulded within a single moulding operation around the walls of a larger mould 2112. If necessary, pallets moulded in this way may be cut or punched out of the sheet of moulded pallets on release from the mould.

In an alternative embodiment, the mould may comprise a plurality of layers of pallet moulds, for example in a cubic or cuboid arrangement.

Preferably, the pallets are moulded using the rocking and rotating methods described in more detail herein.

Fig. 22 illustrates a portion of a mould which may be used to form pallets such as those illustrated in Figs. 17 to 20. The portion of the mould that is illustrated may be used to form the underside of the platform of the pallet, including the pallet feet, which can be seen as recesses in the mould 2210, and the recesses into which the feet of other inverted pallets may be inserted 2212, which can be seen as raised areas of the mould. The central raised sections of the mould 2214 may be provided to form large shallow recesses in the underside of the platform of the pallet. This may decrease the net weight of the pallet without significantly reducing the strength of the pallet.

Fig. 23 is a close-up view of part of the mould portion illustrated in Fig. 22. A recess for a foot of the pallet 2312 and raised portions for forming recesses in the pallet 2310 are illustrated in more detail.

Figs. 25 to 27 illustrate schematically different views of parts of a mould that may be used to form the pallets. In particular, the figures illustrate recesses 2510 to form the feet of the pallet, raised sections to form hollows 2512 within the feet and further raised sections 2514 to form shallow hollows in the platform, as described above.

As described in more detail herein, the pallet is preferably formed from a filled plastics material. At least a portion of the pallet, for example the pallet platform, may have an outer skin layer and an inner layer of a different composition. In one embodiment, the inner layer may be a foamed layer.

In one method of manufacture, pallets and containers may be manufactured in the same location using similar rotational moulding techniques as described herein. This may allow the pallets to be distributed for use within the containers. That is, a batch of pallets may be stacked, preferably nested, within a container and the container, together with the pallets, may be shipped to the required destination. This may be particularly advantageous since a user who requires a container is also likely to require pallets to stack goods within the container.

A method of manufacturing an embodiment of a container, pallets, cable reels, and other similar apparatus using rotational moulding techniques will now be described in more detail. This method is applicable to a wide range of products manufactured from plastics based materials and is not limited to the storage and transportation products described.

Conventional rotational moulding techniques are well known in the art. A feedstock is inserted into a preformed mould. The mould is then placed into an oven to melt the feedstock and the mould is rotated and tilted to cover the interior of the mould with a layer of the melted feedstock. The rotation of the mould may be performed using a spider having a plurality of legs, for example three legs, wherein a mould may be attached to and rotated relative to each leg of the spider and wherein the spider as a whole may also be rotated. Once this stage of the process is complete, the mould is then cooled, for example by removing it from the oven or by cooling the oven itself. During the cooling process, the mould continues to be rotated to ensure it remains evenly coated. Once cooled, the product may be removed from the mould for further processing.

For some applications, rotational moulding may be preferable to, for example, blow moulding or injection moulding, since the process introduces fewer stresses into the moulded product. In addition, components can be incorporated into the rotationally moulded product by positioning the components within the mould before the rotational moulding process begins. The prior art rotational moulding process, however, is slow and inefficient. Each moulding cycle requires a large amount of time to allow the oven to heat to the required temperature and to cool the mould at the end of the heating process. In addition, a large amount of energy is wasted in the heating and cooling cycle.

To alleviate some of the problems with conventional rotational moulding techniques discussed above a new rotational moulding technique and apparatus will now be described with reference to Fig. 1. The apparatus and methods described herein may be used to form all of the products described herein.

As in a conventional rotational moulding technique, the product is preferably formed within a mould 110. The inner surface of the mould is preferably formed with a shape corresponding to the required outer shape of the product, for example a container with a corrugated outer surface may be formed using a mould with a corresponding corrugated inner surface. In the present embodiment, the apparatus further includes an inner mould portion 112, or liner, placed within the outer mould portion 110, hence the product 114 is formed between the surfaces of the inner mould portion 112 and the outer mould portion 110.

In a preferred embodiment, the apparatus described herein is formed substantially in a single moulding operation, for example, the main body of the freight container may be formed in a single piece. Hence a large mould may be required, for example to encompass a container that meets the 40' high-cube specification. Large moulds may also be used to mould a plurality of products in a single moulding operation, for example a number of pallets may be moulded in a single mould. In the case of a container, the container is formed around the outer surface of the inner mould portion 112. In the case of smaller products, such as a pallet, each product is formed between the surfaces of the inner 112 and outer 110 moulds.

To mould the product, a predetermined amount of the feedstock is placed within the apparatus between the inner and the outer mould portions and the mould is heated. The walls of the mould may be heated by any suitable heating means, for example using heating plates embedded in the walls of the mould but, in the present embodiment, the mould is heated by applying direct heating means 118, for example a plurality of gas burners, to the exterior of the mould walls. The mould may then be rotated through the gas burners 118 to heat the mould walls evenly and hence obtain an even thickness of the plastics-based material over the walls of the mould. In the present embodiment, the gas burners are coupled to a bar 116 and the bar is maintained at a constant distance from the mould walls by spring elements. This may ensure that the walls of the mould are heated evenly and to a constant temperature. The compositions described herein may be softened at a temperature of about 160° and may be melted at a temperature of about 220°.

The inner surface of the inner mould portion 112, or liner, is preferably further heated by a gas burner within the liner 120. Hence both the outer mould portion 110 and the liner 112 are evenly heated. This may enable an even distribution of plastics-based feedstock within the mould.

Probes 122 within the mould monitor the temperature inside the mould to determine when the feedstock has melted. Probes 112 may be positioned within the inner mould portion 112 of the apparatus and may monitor the air temperature within the inner mould portion.

A heat shield may further be provided to reflect heat from the gas burners onto the surface of the apparatus.

Figs. 2a, 2b, Fig. 3 and Fig. 4 illustrate further embodiments of apparatus for performing the method described herein. The mould 210 is supported on a carriage 212, which may enable the mould to be rocked and rotated, or spun, to coat the whole of the mould, between the outer mould portion and the inner mould portion, with a layer of the feedstock. It has been found that the surfaces of the mould may be coated sufficiently using only a low rate of rotation and only a small angle of tilting. For example, a rotation rate of about 4 rotations per minute and a tilt cycle rate of about 2 cycles per minute with a maximum angle of inclination of 15° may be sufficient to distribute the melted feedstock over the surfaces of the mould.

Once the interior surface of the mould has been coated, the gas burners may be turned off and the mould may be cooled, for example by rotating the mould through a stream or jet of water or of air. Alternatively, the mould may be cooled using a cooling jacket, for example a water-cooled or oil-cooled jacket.

If a layered product is required, however, it is not necessary to cool the coated mould. Instead, further feedstock may be introduced to the mould, for example a feedstock having a different composition may be introduced, and the mould may continue to be rotated until the second layer of feedstock has covered the inner surface of the first, outer layer. Further layers of material may continue to be added in this way to build up the product.

If there is no inner mould portion in the apparatus, the feedstocks for the further layers may simply be added to the inside of the mould, however, if the first outer layer of the product is formed over the surfaces of an outer and an inner mould portion, it will be appreciated that any further feedstock for a further, inner layer of the product must be inserted within the skin or shell of the outer layer. In the present embodiment, this is achieved by providing areas of the outer mould portion that are covered in a coating to which the melted feedstock does not adhere, as shown at 124 in Fig. 1. For example, for a polyethylene composition, areas on the inner surface of the outer mould portion may be covered with a Teflon (RTM) coating. The non-stick areas of the mould may be removable from the mould leaving apertures 124, preferably small apertures, through the outer mould portion and through the skin formed by the first feedstock, to the interior of the skin formed by the first feedstock. A further feedstock may then be added to the interior of the skin formed by the first feedstock to provide an inner layer for the product. For a container, non-stick areas are preferably provided at diametrically opposite corners of the container mould.

It will be appreciated that it is advantageous to insert the second feedstock into the interior skin of the first feedstock as quickly as possible after the first feedstock has coated the surfaces of the mould. This may allow a better bond to be formed between the two layers and may reduce the cycle time for manufacturing the product. Methods and apparatus for fast and efficient insertion of the second feedstock will be described in more detail below.

As outlined above, it has been found that it is not necessary to cool each layer of the product within the mould before adding a further layer. Rather, simply adding the next layer allows a secure bond to be formed between the layers of the product without significant mixing or blending occurring between the layers.

Once all of the required layers have been added, the mould and the product within the mould may be cooled, preferably by rotating the mould through a jet or stream of water. To decrease the time for the cooling part of the cycle, the cooling means may be applied both to the exterior surface of the outer mould portion and to the interior surface of the inner mould portion.

The methods described above may allow a product, such as a container, or a batch of products, such as a batch of pallets, to be manufactured in a cycle time of about 20 minutes.

Other methods of moulding or forming the products described herein, such as the container, may be used and the products may be moulded in several sections, which may subsequently be joined together. For example, the doors of the container may be moulded separately and then may be joined to the main part of the container. In the present embodiment, the main body of the container and the doors of the container may each be provided with corresponding parts that may be assembled into a piano-type hinge. The two parts of the hinge may be manufactured as part of the door and the main body and the door may be coupled to the main body of the container by inserting a rod through corresponding sections of the hinges.

An embodiment of the container itself will now be described in more detail with reference to Figs. 5 and 6. According to one embodiment, the container is formed as a 40' high-cube container with each wall comprising an outer skin layer 510 and an inner layer 512.

Each layer of the walls of the container comprises a filled plastics-based material containing plastic, a filler and a unifier material, but the relative amounts of the components of the material vary between layers. The outer skin layer 510 preferably comprises a larger proportion of a high-quality plastics material, such as polyethylene, for example the plastics material may comprise about 60% by weight

of the composition, and a smaller proportion of a filler, for example about 40% by weight of the composition. The inner layer 512 preferably contains a relatively high proportion of the filler material, for example about 60% by weight and the foam layer is preferably highly foamed, for example 50% foamed. The foaming ingredient may be, for example, Sodium Bicarbonate. The total thickness of the container walls may be about 60mm, but this may be varied depending on the requirements of the container. In one embodiment, the thickness of the outer skin layer may be about 5-8mm and the thickness of the inner layer may be about 40-60mm. In one embodiment, the walls of the container may be only 30mm thick.

In an alternative embodiment, the inner layer 512 may be formed with a low proportion of filler material or may include no filler material. For example, the inner layer 512 may comprise a plastics material and a foaming agent. In one embodiment, the outer skin layer 510 may comprise a high proportion of filler, for example about 60% by weight filler.

The filler material of the present embodiment is sand, preferably dredged sand, since this has finer particles than desert sand. Alternative filler materials may include ash, a carbonate material such as calcium carbonate, another silicate material such as ground rock, or a salt material such as sodium chloride or an organic material, such as straw, peanut hulls, vegetable waste, miscanthus, wood flour or animal droppings.

The net weight of embodiments of containers as described above may be about 3000 kilograms, preferably about 2800 kilograms, although heavier or lighter containers may also be formed using the techniques described herein. The net weight of a prior art steel container is about 3800-4200 kilograms, so containers as described herein may provide a significant saving in weight, for example on a container ship on which a large number of containers may be transported.

Preferably, the exterior surfaces of the container are not flat surfaces but have raised sections or corrugations 514 as shown in Fig. 5. In addition, the lower surface of the container may be formed with a raised grid of bars, for example in a waffle pattern. This may provide additional strengthening to the lower surface of the container, which may support the majority of the weight of the contents of the container and may further be required to support the weight of loading machinery, such as a fork-lift truck, which may be driven inside the container to load the contents.

An embodiment of a model of a 40 foot container formed according to the methods described herein is illustrated in Fig. 6.

Non-plastic components or pre-formed components may be incorporated into the container during its manufacture. For example, a steel frame may be incorporated into the container by placing the steel frame within the mould and forming the plastic layers of the container around the steel frame. Including a steel frame in the container may increase the strength of the container and may allow weight to be distributed evenly throughout the container structure. It is noted, however, that it has been found that it is not necessary to include a steel frame in embodiments of the container described herein to enable the container to meet the requirements of the industry standards.

Reinforcing eyelets may further be provided in some embodiments of the container, preferably in the four corners of the container, by over-moulding the eyelets into the plastic composition during the moulding process. An embodiment of a reinforcing eyelet is illustrated in Fig. 7. Fig. 8 illustrates one embodiment of an eyelet incorporated into a container manufactured according to the methods and apparatus described herein. The reinforcing eyelets may be used to connect the container to lifting apparatus, such as lifting gantries, and may provide additional strength to the container at these points.

A door fastening or locking mechanism may further be incorporated into the container. Preferably, the door mechanism may be moulded so that is it within the container. The door mechanism preferably comprises a prior art door mechanism as used for the prior art steel containers.

Preferably, the cycle time for manufacturing a container body as described herein, with an outer skin layer and an inner layer, is about 20mins. The container is preferably heated at a carefully controlled rate to ensure that the container walls are of an even thickness and is preferably further cooled at a carefully controlled rate to ensure that the container walls do not become distorted.

In a further embodiment of the container described herein, a fibrous material may be incorporated into the container to further bind the composition and strengthen the container, particularly when it is subjected to tensional or bending forces.

A further product which may be manufactured using the methods and apparatus described herein is a pallet. An embodiment of a pallet is illustrated herein in Figs. 9a and 9b. Traditionally, pallets are manufactured from wood, but a pallet manufactured according to the methods described herein may provide a number of advantages over a prior art wooden pallet. In particular, the usable life of a pallet described herein may be greater than that of a wooden pallet and the present pallets may be more environmentally sustainable than wooden pallets. Freight distributors often do not use wooden pallets more than once to ensure that each pallet used is in good condition for transporting the goods. In addition, it is often not economical to repair broken wooden pallets, since the cost of repair often exceeds the cost of a new pallet.

Figs. 9a and 9b illustrate one embodiment of a pallet, although it will be appreciated that a wide variety of shapes and sizes of pallets may be formed using the methods described herein. The pallet illustrated in Figs. 9a and 9b comprises a platform 910, on which the goods to be transported may be placed or stacked, and a plurality of feet 912. In this embodiment, the pallet comprises nine feet spaced in a regular pattern over the bottom surface of the pallet. The pallet illustrated is a rectangular two-way access pallet, but rectangular or square pallets may be formed and may be designed as four-way access pallets to enable machinery, such as a fork-lift truck, to access and move the pallet from any one of four directions.

Optional bracing members 914 may be provided between some or all of the feet of the pallet as shown in Fig. 9b, however the bracing members are not a necessary feature of the pallet.

The feet of the pallet may contain recesses or hollows, so may not be whole. This may reduce the weight of the pallet.

The pallet is preferably manufactured using a rotational moulding technique. Preferably, a plurality, or batch, of pallets is formed in a single moulding operation. The inner surface of the outer mould portion of the apparatus may be formed with a plurality of indentations, corresponding to the feet of the pallet, and the surface of the inner mould portion of the apparatus may be formed as a flat surface, to provide a pallet with a flat pallet surface to be formed. Alternatively, indentations or texture may be provided on the surface of the inner mould portion to allow a pallet with an uneven or textured platform surface to be formed.

A further embodiment of a pallet is illustrated in Fig. 10. In a preferred embodiment, the pallet comprises an outer skin surface 1010 comprising about 60% by weight of a plastics material, such as polyethylene, preferably HDPE, about 40% by weight of a filler material, such as sand or calcium carbonate, and a small amount of a unifier material. Once the outer skin has been formed in the moulding apparatus, a second foam composition 1012 may be inserted into the outer skin using the method described above, and the inner foam material 1012 may be distributed throughout the outer skin 1010. The foam composition may be introduced as a solid material but may start to foam on the application of heat to the material. In the present embodiment, the foamed material may be 50% foamed.

In one embodiment, the pallet may comprise a single, solid plastics-based filled material and may not include a foam layer. However, including a foam layer may enable the finished pallet to be lighter and

may add strength to the pallet when compared to a solid pallet manufactured with indentations to reduce the amount of plastics-based material used.

Further products may be manufactured using the methods and compositions described herein. For example, fencing or screening material may be provided in sheet form, with or without a foam layer. Building materials, for example panels that may be used as internal or external walls or components that may be used for decking, may further be provided. Similarly, the methods and compositions described may be used to provide ship-building materials, such as a hull for a ship, boat or tanker.

In some embodiments, a plurality of layers may be provided in a product and each layer may comprise a different composition. For example, the upper and lower surfaces of the outer skin layer described herein may be formed separately in different moulding cycles and may be formed from different compositions. In some embodiments, non-plastics based layers, for example metals-based layers, may be incorporated into the product.

The methods described above may be implemented in a moulding plant and an embodiment of a plant is illustrated in Figs. 11 and 12. However, it will be appreciated that a wide variety of manufacturing plants may be used and the plants may be adapted depending on the product being manufactured. The plastics composition feedstocks may be mixed within the plant, or may be mixed and delivered to the plant as raw materials, for example in pellet form. Preferably, the feedstock may be formed by mixing the components and forming pellets from the mixed components. Preferably, the unifier may be mixed with the filler before the polymer is added to the mixture.

The plant illustrated in Fig. 11 includes a central container area 1110 comprising a plurality of containers 1112, each containing a preformed feedstock. A plurality of mobile feedstock machines 1114 obtain a predetermined quantity of feedstock from the central containers 1112 and deliver them to each of a plurality of moulding apparatus 1116.

As illustrated in Figs. 12 and 13, the feedstock machines 1210 insert the feedstock into the moulding apparatus 1212. It has been found that it is advantageous to tilt the moulding apparatus 1212 to enable the feedstock to be delivered efficiently to the moulding apparatus 1212. The feedstock machines 1210 are preferably provided with telescopic arms 1214 and telescopic delivery buckets 1216 for delivering the feedstock to the moulding apparatus 1212 along the whole length of the apparatus. This may be particularly advantageous when inserting the second feedstock into the moulding apparatus 1212, since inserting the feedstock along the whole length of the apparatus may enable the feedstock to be inserted more quickly into the apparatus, while the first feedstock is relatively fluid. The telescopic delivery bucket 1216 preferably extends to a length of about 12m, so it may extend the whole length

of a container mould, and preferably holds a predetermined amount of feedstock. Preferably, the bucket 1216 is divided into a plurality of sections, each of which holds a predetermined amount of feedstock.

Properties of compositions described herein will now be outlined in more detail. The description below is provided by way of example only and the compositions and parameters provided are not intended to be limiting. The mouldings described were carried out under the following moulding conditions:

Oven temperature = 300 C
Rotation ratio ≈ 4:1
Cooling medium = Forced air
Sheet steel test mould

All cycle times are taken from the same start and end point to allow for easier comparisons of the various stages in the internal air temperature traces. For each moulding carried out, Polyethylene was mixed with sand in a 50:50 mixture by mass. To this mixture, different levels of unifier were added from 1 % by weight to 10% by weight.

The polyethylene grade used was a rotomoulding grade, RG 7243 produced by Borealis in Norway, this material is a standard LLDPE grade with a density of 924kg/m^3 and a MFI of 4.5.

Grade	Cycle Time (min)
T963	20.17
T964	22.35
T965	21.7
T966	22.77
T967	22.05
T968	22.87
T969	22.06
T970	22.07
T971	23.23
T972	22.94
Polyethylene	33.23

It can be seen from the data above that the cycle time of each filled moulding is not affected by the addition of different levels of unifier but there is a substantial difference between the filled and the

polyethylene mouldings. It is assumed that difference is due to the filled mouldings containing half the amount of PE as the polyethylene mouldings.

Standard tensile test specimens were produced from the filled mouldings using a die. The specimens were tested on an Instron 4411 tensile testing machine at a crosshead speed of 20 mm/min (as per standard ASTM 638). The data provided below shows the mechanical properties of each of the grades tested. A standard unmodified polyethylene grade is also added as a comparison.

Grade	Stress at Break (MPa)	Strain at Break (%)	Modulus (MPa)
T963	1.95	21.9	172.0
T964	2.13	22.4	141.6
T965	1.65	17.7	131.0
T966	1.68	13.3	153.0
T967	2.10	21.5	142.9
T968	1.16	8.2	121.6
T969	2.52	19.7	108.7
T970	2.24	20.5	113.4
T971	1.17	11.3	128.5
T972	1.05	9.6	101.2
Standard	--	--	223

There is a lot of scatter in the values of the mechanical properties determined for all the grades tested. However, the general trend shows a decrease in modulus as the percentage of unifier is increased.

Figs. 14, 15 and 16 illustrate graphically the properties of the filled compared to polyethylene as described above.

As will be appreciated by one skilled in the art, aspects of the invention may provided independently and features of one aspect may be applied to other aspects. It will also be appreciated that the methods described herein may be used to manufacture a wide range of products and the invention is not limited to the products described herein.

A further embodiment of a pallet will now be described with reference to Figs. 46 to 58, which illustrate pallets and pallet elements according to a further embodiment. The pallets illustrated in Figs. 46 to 58 comprise top and bottom pallet elements of different designs.

Fig. 46 illustrates a side view of a top pallet element, Fig. 47 is a perspective view of the under-side of a top pallet element and Fig. 48 is a perspective view of the top-side of a top pallet element according to the present embodiment.

As illustrated in Figs. 46 to 48, the top pallet element comprises a platform, or pallet surface 4610 and a plurality of feet, the feet comprising tapered sections 4612 and interlocking sections 4614. In the present embodiment, the interlocking sections 4614 of the top pallet element comprise protrusions, or male interlocking sections. In the present embodiment, one interlocking section 4614 is provided per foot but, in alternative embodiments, only some of the feet may be provided with interlocking sections 4614 or more than one interlocking section 4614 may be provided on each foot. Preferably, nine feet are provided on the lower surface of the pallet element.

The upper and lower surfaces of the pallet platform 4610 include raised ridges and/or indented hollows 4710, 4810. This may improve the drainage of fluid from the surface of the pallet, may enable air to circulate under the products stacked on the pallet and/or may improve the grip for products stacked on the pallet surface. The platform 4610 may further be provided with an uneven upper surface, for example via small ridges 4812, to improve the grip of products stacked on the platform 4610. In the present embodiment, the platform is preferably a continuous surface, which may enable small and/or delicate items to be carried on the pallet.

The pallet feet 4712 are preferably hollowed 4814 from the top surface of the platform 4610. This may reduce the overall weight of the top pallet element, facilitate moulding of the element and/or enable pallet elements to be stacked, as described in more detail below.

Figs. 49 to 51 illustrate a bottom pallet element according to one embodiment. Fig. 49 is a plan view of the top of a bottom pallet element, Fig. 50 is a perspective view of the under-side of a bottom pallet element and Fig. 51 is a side view of a bottom pallet element according to the present embodiment.

The bottom pallet element also includes a platform 4912 and a plurality of hollowed feet 4910. The surface may also include raised ridges or indented hollows 4916 and smaller ridges or an uneven surface 4914. However, the platform 4912 of the bottom pallet element preferably includes sections that have been cut away 4918. This may reduce the overall weight of the pallet element without significantly reducing its strength, which may allow pallets to be more heavily loaded or may allow more pallets to be transported, for example in a container.

As illustrated in Fig. 50, the feet of the bottom pallet elements preferably comprise tapered sections 5010 and interlocking sections 5012. Preferably, the interlocking sections 5012 comprise hollow

sections, or female interlocking sections, that correspond to the male interlocking sections of the top pallet elements.

Preferably, the male interlocking sections 4614 of the top pallet elements and the female interlocking sections 5012 of the bottom pallet elements couple together when the lower side of a bottom pallet element (the surface illustrated in Fig. 50) is presented to the lower side of a top pallet element. The interlocking sections may couple, clip or "click" together. For example, the male interlocking elements may fit closely inside the female interlocking elements or a raised ridge on one interlocking element may clip within a hollow on the surface of the other interlocking element. The feet of the pallet elements may be designed to interlock and release on manual pressure. In one embodiment, however, the feet may interlock only on the application of force, for example from a mallet. This may allow the feet to be interlocked together more securely and may prevent the pallet elements from separating during use.

Fig. 51 illustrates a side view of a bottom pallet element according to one embodiment, including tapered pallet feet 5010 and a pallet platform 4912.

Figs. 52 to 55 illustrate pallets according to one embodiment, wherein each pallet comprises a top pallet element 5210 and a bottom pallet element 5212 and wherein the feet of the top pallet element 5214 couple securely to the feet of the bottom pallet element 5216. The top pallet element 5210 includes a continuous, solid pallet surface, and the bottom pallet element 5212 includes apertures, reducing the overall weight of the pallet.

Fig. 52 is a perspective view of the under-side of the pallet comprising connected top and bottom pallet elements, Fig. 53 is a perspective view of the top-side of the pallet comprising connected top and bottom pallet elements, Fig. 54 is a further perspective view of the top-side of a pallet comprising connected top and bottom pallet elements and Fig. 55 is a plan view of the under-side of a pallet comprising connected top and bottom pallet elements according to the present embodiment.

Figs. 56 and 57 illustrate top and bottom pallet elements arranged in a stacked configuration. In a preferred embodiment, when the bottom pallet elements 5610 are inverted and placed on top of the top pallet elements 5612, the bottom pallet elements 5610 stack closely inside the top pallet elements 5612, since the feet of the bottom pallet elements fit within the hollows in the top of the feet of the top pallet elements.

In a preferred embodiment, however, the top pallet elements 5612 do not stack closely inside the inverted bottom pallet elements 5610. Hence, when a plurality of pallet elements are stacked, as shown

in Figs. 56 & 57, the stack is formed of pairs 5614 of nested top and bottom pallet elements, with spaces between each pair 5616. This may allow the stack of pallet elements to be separated into pairs 5614 easily, for example automatically, before each pair 5614 is assembled into a pallet. However, enabling the bottom pallet elements 5610 to nest closely with the top pallet elements 5612 reduces the amount of space needed to store and/or transport each unloaded and unformed pallet.

Fig. 58 illustrates a plurality of stacked pallet elements being transported on a fork lift truck. As illustrated in Figs 56 to 58, the bottom pallet 5618 in the stack of pallets is preferably formed into a pallet. This may allow the stack of pallets to be handled by standard machinery, such as the fork lift truck illustrated in Fig. 58.

Figures 28 to 45, which illustrate some of the tests that the pallet embodiments described above should meet, will now be discussed. The description of the pallet and the tests set out below is not intended to be limiting in any way and practical pallets may be required to pass further tests or fewer tests before the pallets are used. The tests applied to the pallet may depend on the intended use of the pallet.

The typical pallet referred to below may be a dual pallet, created by turning one pallet through one hundred and eighty degrees and fixing the legs of the each of the pallets to the opposing base, as shown in Figs. 18, 19 and 24 for example. Such a pallet 2810 is shown in Fig. 28, and typically is a 1200 mm x 1000 mm (48 inch x 40 inch) rackable four way entry type, with a full perimeter base. The pallet has a rated load of 1270 kg (2800 lb). The total mass of the finished pallet in the dry-as-moulded condition at room temperature, inclusive of fire retardant solution, is less than 22.7 kg (50lb).

Embodiments of the pallet may have a service life of in excess of ten years, and an example of such a pallet is described below.

Four edges 2812, 2814, 2816, 2818 of the pallet are blue and the pallet contains an ultraviolet stabiliser to ensure that there is no visible colour shift during the life of the pallet. This can be measured by an ultraviolet resistance test based on a three-year Arizona direct sunlight exposure. The colour shift can be measured on a Macbeth 7000 Colorimeter.

The gloss on the top of a top deck 2820, on the top of a bottom deck 2822, and on a spacer 2824 exterior is between 0 and 20 units of gloss. This means that these portions of the pallet are flat to semi-gloss.

The surface finish of the pallet is opaque and non-reflective. This ensures compatibility with optical sensing equipment on pallet conveyers, and so on. The top of the top deck 2820, top of the bottom

deck 2822 and spacer 2824 exterior are surfaced textured, for example to Mold-Tech MT-105503 (20μ) or MT-1055-2 (15μ). Surface imperfections or irregularities that detract from the aesthetics of the pallet are minimised.

The pallet has a marking 2826 branded indelibly in white on the leftmost space of both sides. The marking 2826 may be the logo of the company to whom the pallet belongs. A second marking 2828 is branded indelibly in white on the lower half of the rightmost spacer of both sides and is the company's telephone number and "Property of [the company]". A third marking 2830 on a spacer block on one side of the pallet is the manufacturer's name and logo. All three markings 2826, 2828, 2830 are resilient to high-pressure steam cleaning and to normal handling and use of the pallet.

A code 2832 comprising the week number, month and year of manufacture of the completed pallet assembly is marked on a spacer on the 1m side, such that it is reasonably protected from damage or wear. An appropriate recycle code 2834, in accordance with Society of Plastics industry guidelines is permanently moulded in a conspicuous area of the pallet. If different materials are used on a pallet, each component is so marked.

The pallet does not contain any halogenated compounds - i.e. compounds that are formed from fluorine, chlorine, bromine, iodine or asatine. Nor does it contain any heavy metals, such as silver arsenic, barium, selenium, lead, mercury, cadmium or hexavalent chromium. No restricted materials are used in its manufacture.

All materials used in the pallet are capable of being recycled. Preferably the materials used can be recycled through viable and sustainable technologies i.e. technology exists to use the recycled materials in existing product feedstreams.

Exposed areas of the pallet are resistant to attack by common industrial and household chemicals, including cleaning agents, aerosols, gasoline etc.. This requirement may be validated as follows...

The damage rate per trip is defined as the ratio of the number of pallets at the end of a single trip that have suffered non-abusive damage, to the total number of pallets in the trip. This will be assessed during a field trial once the pallets have successfully passed all other tests. The cumulative average damage rate is an accumulative average damage rate of pallets that are inspected during the field trial. Data in this trial is collected until the cumulative average damage rate reaches steady state, providing that a minimum of 1000 pallets are inspected. Steady state is defined as when the last quartile of the cumulative damage rate, based on the number of pallets that are inspected, is contained in a band that

is ±10% of the current cumulative average damage rate. At this point the damage rate per trip will be calculated. The damage rate per trip for the embodiment is less than, or equal to 0.25%.

The following will be considered abusive damage to the pallet, all other damage being considered non-abusive:

- damage resulting from being dropped from a height that is greater than 3m;
- damage resulting from supporting a load which is greater than 1270 kg (2800 lb);
- fork tine tip damage to top of the top deck, bottom of the top deck or to the bottom of the bottom deck (excluding damage to deck edges);
- damage to internal ribbing of spacers, resulting from high speed impact by fork handling equipment; and
- complete separation of top and/or bottom deck from any spacer.

The pallet does not contain any residual monomers, residual solvents, or other volatile substances that may contaminate products under load, and is compatible with fat-containing foods. The pallet material does not emit or absorb noxious or toxic substances, or strong odours.

Liquid dirt and foreign body entrapment is limited, and the design of the pallet allows for easy drainage. The pallet material is non-porous and non hydroscopic and does not craze, crack or pit during normal use of the pallet. Preferably the pallet has anti-static properties in order to limit the accumulation of dust.

The design of the pallet, and the materials used do not support microscopic growth. Furthermore the design allows for the circulation of air through the pallet in order to facilitate pallet drying, load cooling, fruit ripening etc..

The pallet is easy to clean and dry and designed to withstand multiple cleaning cycles, either manual or automatic, throughout its service life. Top deck openings 2836 (only some of which are shown) are through holes and tapered so that the smaller openings are at the top of the top deck and the larger openings are at the bottom of the top deck.

In order to make cleaning easier, a minimum radius of 3.175 mm (1/8 inch) is present on all internal radii on the bottom of the top deck and on the bottom of the bottom deck. In addition, a minimum slope of 3 degrees is present across the top of the bottom deck for good drainage.

Examples of suitable cleaning methods are washing the pallet with detergent and high-pressure water at 100 degrees centigrade for ten minutes, and washing the pallet with high-pressure steam at 827 kPa (120 psi) for ten minutes.

After being thoroughly rinsed with water at 22°C±2°C, and allowed to air-dry at 22°C±2°C, the pallet retains no more than 20g of water.

A radio-frequency identification (RFID) tag 2838 is housed in the centre spacer, in order to provide a unique identification mechanism for each pallet. The RFID tag 2838 is housed by insertion, but could equally be housed by some other suitable method, such as encapsulation. The tag 2838 is removable and may be reusable.

The RFID tag 2838 shown is a passive tag, and contains only the identification number of the pallet. Alternatively, however, an active tag could be provided which would contain further information, such as details of the pallet's characteristics (for example the load it can bear) or details of the current load carried on the pallet.

The tag 2838 operates in the high frequency range (13.56 MHz), but could operate in another range, such as the ultra-high frequency range (868 to 956 MHz). The area where the tag is attached is free of cooling lines or other encumbrances in order to facilitate RFID. Alternatively, or in addition, a bar code may be included on a corner spacer on both sides.

The pallet may be used with a wide variety of different handling equipment. It is compatible with automatic storage and retrieval systems, racking systems, hand pallet jacks, fork lift trucks, conveyors and packaging equipment such as banding machines, stretchwrap machines, palletisers and depalletisers and stackers and destackers.

Typically the products carried on the pallet are packaged in cardboard or corrugated boxes, plastic or paper bags, plastic crates, sacks, or plastic or metal containers. Slip-sheets may, or may not be used. The products may be stretchwrapped, bandwrapped or loose. The pallet has a lug 2840 on which the stretch film leader may be secured in order to start the stretchwrapping process. Naturally, the pallet may also be used to carry packaging materials, such as cardboard, paper, woven sacks etc..

The bottom of the pallet is relatively level, the bottom deck coverage (that area which makes intimate contact with a flat plate when brought to rest on the bottom deck) being more than 55%. It does not contain protuberances that could damage corrugated layer boards when load containing pallets are stacked on top of each other.

Any openings in the top deck are sized and located such that the packaged goods are adequately supported. This prevents damage to the goods. The pallet is compatible with edge clamping machines that have a maximum clamp load of 3969 kg (8750 lb).

The tests which pallets of the embodiment described above meet will now be described. Every sample is individually required to meet, or exceed, the test criteria.

For the static load tests and the slip resistance tests, the test sample size is determined as follows (see Figure 29):

i. Using an initial sample size of three (3), perform each test as specified and measure all required variables for the test, e.g. deflection, window height, etc.

ii. The primary variable will be used to determine final sample size. For all static load tests, the primary variable is *deflection*. For slip resistance tests, the primary variable is *coefficient of static friction*.

iii. Determine the 95% confidence interval of the mean of the primary variable data using the One Sample t-Test (or similar statistical test).

iv. Determine if at least one of the following is true:

   a) The mean value of the primary variable data does not meet the specified pass/fail criterion

   b) *Static Load Tests*: The upper confidence limit of the 95% confidence interval of the primary variable data plus three standard deviations is less than the pass/fail criterion
   Slip Resistance Tests: The lower confidence limit of the 95% confidence interval of the primary variable data minus three standard deviations is greater than the pass/fail criterion

   c) The 95% confidence interval lies within 12.5% of the <u>mean</u> of the primary variable data

v. If the primary variable data does not satisfy any <u>one</u> of the above checks (a, b or c), test additional samples (thus incrementing the sample size), and measure all required variables for the test.

vi. Add the primary variable data of the additional test(s) to the initial data set, and repeat steps (iii) and (iv)

vii. If the primary variable data satisfies at least one of the above checks (a, b or c), record the sample size and stop testing.

viii. Check the pass/fail criteria specified for each test

The tests use either of three different load types, the first of which is a uniform rigid load. The second is a uniform granulated load shown schematically in Figure 30a and Figure 30b. This load is made up of individual sandbags 3010, each weighing 9 kg ± 0.9 kg (20 lb ± 2lb). The sandbags 3010 are placed in alternating layers (layer A and layer B) on the pallet, as shown in Figure 30a and Figure 30b. There are 14 sandbags 3010 per layer, i.e. 126 kg (280 lb) per layer.

The third type of load is a uniform flexible load, which is provided by an inflatable bag or airbag. When fully inflated the airbag dimensions are between 1200 mm x 1000 mm (48" x 40") and 1225 mm x 1025 mm (49" x 41").

Pallet Spacer Compression (Creep)

This test determines maximum pallet spacer deflection during long term creep, and enables the compressive strength of block stacked pallet spacers 3110 to be evaluated. The test is performed in general accordance with ASTM D1185-98a "Standard Test Methods for Pallets and Related Structures Employed in Materials Handling and Shipping", ASTM 1998.

A set-up schematic for the test is shown in Figure 31. The test uses a load 3112 which may be either a uniform rigid load or a uniform flexible load. The sample size is determined using the procedure shown in Figure 29. The other parameters of the test are as follows:

- Datum load: Do not apply a datum load
- Rated Load, R: 2800lb
- Maximum number of pallets in Stack, M: 5
- Test Load: 1.1xMxR, i.e. 15,400lb
- Test Load Type: Uniform rigid over entire pallet
- Test Temperature(s): 40°C±2°C
- Test Duration: 720 hours (A shorter test duration may be used, provided that a correlation is established by experiment between the shorter duration test and 720 hours)
- Deformation Rate: Decreases under test load with time
- Spacers shall not be tested individually, but as part of a complete pallet
- <u>Measured Variables</u>:
    - Maximum spacer deflection, Δy, versus time (<u>not</u> average deflection)
    - Maximum residual deflection after one hour at 23°C±2°C, δ_{Rmax}

Upon conclusion of the creep test, immediately test each pallet to failure at 23°C±2°C, using a uniform rigid load. Record the load at failure.

Pallet Spacer Tine Compression

This test evaluates the resistance of pallet spacers to horizontal static loads, in an attempt to replicate the forces encountered when pallets are moved or manoeuvred into place using fork tines.

The test is performed on a compression test machine by securing the pallet under test with the decks positioned perpendicular to the ground. The load is applied by a tine-like applicator which is shown in Figure 32, individually on each spacer to be tested. The test set-up is shown schematically in Figure 33. A uniform rigid load 3310 is applied through a load applicator 3312 to a pallet spacer 3314.

Edge Rack Support (Creep)

This test enables the maximum pallet deflection during long term creep and the pallet bending strength to be determined for when the pallets are edge racked. The test is performed in general accordance with ASTM D1185-98a in both length and width directions. The test set-up is shown in Figure 34, a uniform granular or flexible load 3410 being applied across a span 3412 of the pallet. The test parameters are as follows:

- Datum load: Do not apply a datum load
- Test Load: 2800lb (Do not use 1.25xMxR)
- Test Load Type: Uniform granular (sandbag)[2]
- Test Temperature(s): 40°C±2°C
- Test Duration: 720 hours[3]
- Test Spans: 44" racked across length; 36" racked across width
- Deflection Measurement Location: Maximum pallet deflection location; Residual deflection at maximum deflection location; All measurements taken relative to top of supports
- Deformation Rate: Decreases under test load with time
- <u>Measured Variables</u>:
  - Maximum pallet deflection, δ_{max}, versus time
  - Minimum window height, h, at end of test
  - Maximum residual deflection after one hour at 23°C±2°C, δ_{Rmax} at end of test

Upon conclusion of the creep test, immediately test each pallet to failure at 23° C±2°C, using a uniform flexible load. Record the load at failure.

2 A uniform flexible (airbag) load may be used, provided that the relationship between the airbag and the sandbag loads is determined, and the appropriate scaling factor(s) is/are applied to the results that are obtained from using an airbag.

3 The test duration may be reduced to 72h, and data may be extrapolated to 720h using $y=y_0+a^*\ln(x-x_0)$, where y is the deflection at 720h, and y_0 and a are derived from non linear regression analysis using a three-parameter logarithmic equation (convergences≤1e-4; step size=1).

Short Span Support (Creep)

This test determines the maximum pallet deflection during long term creep and pallet bending strength when rack supports are not at the pallet edges. The test set-up is shown in Figure 35, a uniform granular or flexible load 3510 being applied. It is performed in general accordance with ASTM D1185-98a, the sample size being determined as set out in Figure 29. The test parameters are as follows:

- Datum load: Do not apply a datum load
- Test Load: 2800lb (Do not use 1.25xMxR)
- Test Load Type: Uniform granular (sandbag)[2]
- Test Temperature(s): 40°C±2°C
- Test Duration: 720 hours[3]
- Test Support Width: 2 inch [50.8mm]
- Test Support Location: Mid-span between pallet spacers
- Deflection Measurement Location: Maximum pallet deflection location; Residual deflection at maximum deflection location; All measurements taken relative to top of supports
- Deformation Rate: Decreases under test load with time
- <u>Measured Variables</u>:
    - Maximum pallet deflection, δ_{max}, versus time
    - Minimum window height, h, at end of test
    - Maximum residual deflection after one hour at 23°C± 2°C, δ_{Rmax}, at end of test

Upon conclusion of the creep test, immediately test each pallet to failure at 23°C±2°C, using a uniform flexible load. Record the load at failure.

Fork Tine Support

This test enables the maximum pallet deflection during short term creep, and the pallet bending strength to be determined when pallets are supported by fork handling equipment. The test set-up is shown in Figure 36, a uniform granular load 3610 being applied across a span 3612. The test is performed in general accordance with ASTM D1185-98a, the sample size being determined as shown in Figure 29. The test parameters are as follows:

- Datum load: Do not apply a datum load
- Rated load, R: 2800lb
- Test Load: 1.25xR:3500lb
- Test Load Type: Uniform granular (sandbag)[2]
- Test Temperature(s): 40°C±2°C
- Test Duration: 0.5 hour
- Test Support Width: 4 inch [101.6mm]
- Test Spans: 20 for both 40" and 48" sides
- Deflection Measurement Location: Maximum pallet deflection location; Residual deflection at maximum deflection location; All measurements taken relative to top of supports
- Deformative Rate: Decreases under test load with time
- <u>Measured Variables</u>:
  - Maximum pallet deflection, δ_{max}, versus time
  - Maximum residual deflection after one hour at 23°C±2°C, δ_{Rmax}, at end of test

Stacked Load Support - Top/Bottom Deck (Creep)

This test determines the maximum top deck deflection of the lowest pallet in a stack during long term creep, and the pallet bending strength, when the pallets are block stacked. As the pallets are reversible only the top deck stacked load support needs to be determined, but if non reversible pallets are used the bottom deck support of the second from bottom pallet in a stack can be determined in a similar manner by inverting the pallet so that the top deck is uniformly supported and applying the load to the bottom deck. The test set-up is shown in Figure 37 (Top Deck), or Figure 38 (Bottom Deck), a uniform granular or flexible load 3710, 3810 is applied to the top deck 3712 or the bottom deck 3812 of the pallet. The test is performed in general accordance with ASTM D1185-98a, the sample size being determined as shown in Figure 29. The test parameters are as follows:

- Datum load: Do not apply a datum load
- Rated Load, R: 2800lb
- Maximum Number of Pallets in Stack, M: 5
- Test Load: 1.15xMxR, i.e. 16,100lb[4]
- Test Load Type: Uniform granular[5] (sandbags) or uniform flexible[4] (airbag)
- Test Temperature(s): 40°C±2°C
- Test Duration: 720 hours[1]
- Deflection Measurement Location: Maximum pallet deflection location; Residual deflection at maximum deflection location; All measurements taken relative ground
- Deformation Rate: Decreases under test load with time
- <u>Measured Variables</u>:

- Maximum pallet deflection, $\tilde{o}_{max}$, versus time
- Minimum window height, h, at end of test
- Maximum residual deflection after one hour at 23°C±2°C, $\tilde{o}_{Rmax}$, at end of test

Upon conclusion of the creep test, immediately test each pallet to failure at 23°C±2°C, using a uniform flexible load. Record the load at failure.

[4] The test load on the top deck may be reduced to 1.15xMxRx0.65, i.e. 10,465lb, if a uniform flexible (airbag) test load is used.

[5] It is only necessary for sandbags to constitute the first 2800lb of the test load. Any other load type may be used to make up the balance of the test load

Conveyer Support (Line Load) (Creep)

This test enables the maximum pallet deflection during long term creep and the pallet bending strength to be determined when pallets are supported on conveyors, such as short-span chain conveyors, long span roller conveyors etc.. The test set-up is shown in Figure 39 and it is performed using a uniform granular or uniform flexible load 3910 in general accordance with ASTM D1185-98a, in both length and width directions, the sample size being determined as shown in Figure 29. The test parameters are as follows:

- Datum load: Do not apply a datum load
- Test Load Type: Uniform granular (sandbag)[6]
- Test Temperature(s): 40°C±2°C
- Test Duration: 24 hours
- Test Support Width: 625 inch [15.9 mm]
- Test Support Location: Mid-span between pallet spacers
- Deflection Measurement Location: Maximum pallet deflection location; Residual deflection at maximum deflection location
- Deformation Rate: Decreases under test load with time
- <u>Measured Variables</u>:
    - Maximum pallet deflection, $\tilde{o}_{max}$, versus time
    - Minimum window height, h, at end of test
    - Maximum residual deflection after one hour at 23°C±2°C, $\tilde{o}_{Rmax}$, at end of test

Upon conclusion of the creep test, immediately test each pallet to failure at 23°C±2°C, using a uniform flexible load. Record the load at failure.

Load Cycling (Re-creep)

This test determines the maximum pallet and residual deflections during short-term creep, after cyclical edge rack support loading. The test set-up is shown in Figure 41 and it is performed using a uniform granular or uniform flexible load 4110 in general accordance with ASTM D1185-98a, in the length direction, using an on/off load sample. The load cycle definition is shown in Figure 40. The test parameters are as follows:

- Datum load: Do not apply a datum load
- Test Load: 2800lb (Do not use 1.25xMxR)
- Test Load Type: Uniform granular (sandbag) or uniform flexible (airbag)[6]
- Test Temperature(s): 40°C±2°C, 23°C±2°C
- Load Cycle: 20 hours "load **on**" @40°C, 4 hours "load **off**" @23°C (see figure 12.)
- No. of Cycles: 4
- Test Span: 44", racked across length
- Deflection Measurement Location: Maximum pallet deflection location; Residual deflection at maximum deflection location
- Deformation Rate: Decreases under test load with time
- <u>Measured Variables (see figure 12)</u>:
  - Maximum pallet deflection, δ_{max}, at the beginning of the first cycle, and at the end of each "load **on**" cycle (while still under load)
  - Residual deflection, δ_R, at the middle of each "load **off**" cycle
  - Minimum window height, h, two hours after the end of the fourth "load **on**" cycle

Upon conclusion of the re-creep test, immediately test each pallet to failure at 23°C±2°C, using a uniform flexible load. Record the load at failure.

[6] Edge rack support load testing of the CHEP 48" x 40" block pallet has demonstrated very little difference in deflection data between distributed 20lb-sandbag loads and an airbag load.

Deck Separation

This test enables the resistance to separation of the top and bottom decks from the spacers to be assessed during handling by hand pallet trucks. The test is performed in a load compression test machine by securing the pallet under test as shown in Figure 42. The load is applied vertically by an L-shaped applicator 4210, on the 1000 mm side. The test parameters are as follows:

- Sample size / Type: 2 / Full pallets
- Test Load Type: Uniform rigid
- Test Temperature(s): 23°C±2°C

- Test Duration: Instantaneous
- Platen Speed: 50mm/min
- Deformation Rate: Decreases under test load with time
- Measured Variable: Load at failure

Slip Resistance Testing

The slip resistance is defined as the coefficient of static friction between two specified surfaces, as set out in Table 1. The coefficient of static friction, μ_s, is:

$$\mu_s = \frac{F_H}{F_N}$$

F_H = Horizontal force required to *just* overcome static friction and move one surface relative to another.

F_N = Normal force acting at the mating surfaces (sum of datum load and pallet weight).

	Specified Surfaces	
Configuration	**Pallet Surface**	**Test Surface**
Non-plastic Load-on-pallet	Pallet top deck	Polished steel plate
Plastic Load-on-pallet	Pallet top deck	60cmx40cm 1st Gen. Rehrig Pacific RPC Type 6420
Pallet-on-pallet	Pallet top deck	Pallet bottom deck
Pallet-on-forks	Bottom of top deck	Polished steel forks
Pallet-on-ground	Bottom deck	Polished steel plate

Table 1: Slip Resistance Test Matrix

Non-plastic Load-on-pallet (Top of Top Deck)

This test evaluates the traction between unitised non-plastic loads (such as corrugated boxes) and the pallet top deck. The number of samples is as set out in Figure 29. The test set-up is shown in Figure 43, and uses a polished steel plate 4310. The test parameters are as follows:

- Perform the test under wet and dry conditions; for wet conditioning, wet completely the pallet surface to be tested while the pallet is horizontal, then hold the pallet in a vertical position for 5 seconds and allow the excess water to drain off under gravity; test immediately
- Test Temperature(s): 23°C±2°C (wet and dry); -20°C±2°C (dry only)

- Invert pallet, and place it top-deck-down on a flat polished 40"(min.) x 48"(min.) steel plate that is free of corrosion, scale or any other surface imperfection that may affect surface roughness
- Apply a uniform datum load of 100lb to the bottom deck of the inverted pallet
- Pull the pallet at a uniform rate of 25mm/min until the pallet just begins to move
- Measured Variable: Maximum load to *just* move the pallet, F_H
- Calculate the coefficient of static friction, μ_s, using equation (1)
- Perform the test in both the 48" and 40" directions

Plastic Load-on-pallet (Top of Top Deck)

This test evaluates the traction between unitised plastic loads (such as reusable plastic containers (RPCs)) and the pallet top deck. The number of samples is as set out in Figure 29. The test set-up is similar to that shown in Figure 43 and the test parameters are as follows:

- Perform the test under wet and dry conditions; for wet conditioning, wet completely the pallet surface to be tested while the pallet is horizontal, then hold the pallet in a vertical position for 5 seconds and allow the excess water to drain off under gravity
- Test Temperature(s): 23°C±2°C (wet and dry); -20°C±2°C (dry only)
- Plastic Load Type: 1st Generation Rehrig Pacific RPC type 6420
- Configure the RPC's as a fist layer (any configuration that maximizes pallet top deck space will be acceptable), and band them together by strapping them so that they form a unitised load
- Place the unitised layer on the pallet, so that the pallet top deck is in contact with the RPC bases
- Apply a uniform datum load of 100lb to the unitised layer (by placing suitable weights in each RPC)
- Pull the unitised layer at a uniform rate of 100mm/min until the unitised layer just begins to move
- Measured Variable: Maximum load to *just* move the pallet, F_H
- Calculate the coefficient of static friction, μ_s, using equation (1)
- Perform the test in both the 48" and 40" directions

Pallet-on-pallet (Top of Top Deck)

This test evaluates the traction between two pallets, such as when the pallets are stacked empty. The number of samples is as set out in Figure 29. The test set-up similar to that shown in Figure 43 and the test parameters are as follows:

- Perform the test under wet and dry conditions; for wet conditioning, wet completely the pallet surface to be tested while the pallet is horizontal, then hold the pallet in a vertical position for 5 seconds and allow the excess water to drain off under gravity
- Test Temperature(s): 23°C±2°C (wet and dry); -20°C±2°C (dry only)
- Select one new plastic pallet with a clean, defect-free, bottom deck as a test control pallet
- Place the pallet to be tested on a level surface, bottom deck down, and secure it to prevent movement
- Place the test control pallet, bottom deck down, on the pallet to be tested, in the same orientation as the pallet to be tested
- Apply a uniform datum load of 100lb to the top deck of the test control pallet
- Pull the test control pallet at a uniform rate of 25mm/min until the test control pallet just begins to move
- Measured Variable: Maximum load to *just* move the pallet, F_H
- Calculate the coefficient of static friction, μ_s, using equation (1)
- Perform the test in both the 48" and 40" directions
- Use the same test control pallet for all tests

Pallet -on-Forks (Bottom of Top Deck)

This test evaluates the traction between the bottom of the top deck and fork lift handling equipment, such as fork lift trucks. The number of samples is as set out in Figure 29. The test set-up and parameters are as follows:

- Perform the test under wet and dry conditions; for wet conditioning, wet completely the pallet surface to be tested while the pallet is horizontal, then hold the pallet in a vertical position for 5 seconds and allow the excess water to drain off under gravity
- Test Temperature(s): 23°C±2°C (wet and dry); -20°C±2°C (dry only)
- Support the pallet on two 4"-wide x 48" -long (min.), flat polished steel supports that are free of corrosion, scale or any other surface imperfection that may affect surface roughness
- Place the supports such that they are perpendicular to the window opening, and are in minimal contact with any anti-slip features, if present
- Apply a uniform datum load of 100lb to the top deck of the pallet
- Pull the pallet at a uniform rate of 25mm/min until the pallet just begins to move
- Measured Variable: Maximum load to *just* move the pallet, F_H
- Calculate the coefficient of static friction, μ_s, using equation (1)
- Perform the tests in both the 48" and 40" directions

Pallet-on-Rack / Pallet-on-conveyors (Bottom of Bottom Deck)

This test enables the traction between the pallet bottom deck and steel racks or conveyors (roller, skate-wheel, chain etc.) to be evaluated. The number of samples is as set out in Figure 29. The test set-up and parameters are as follows:

- Perform the test under wet and dry conditions; for wet conditioning, wet completely the pallet surface to be tested while the pallet is horizontal, then hold the pallet in a vertical position for 5 seconds and allow the excess water to drain off under gravity
- Test Temperature(s): 23°C±2°C (wet and dry); -20°C±2°C (dry only)
- Place the pallet bottom deck down on a flat polished 40"(min.) x 48"(min.) steel plate 4310 that is free of corrosion, scale or any other surface imperfection that may affect surface roughness
- Apply a uniform datum load of 100lb to the top deck of pallet
- Pull the pallet at a uniform rate of 25mm/min until the pallet just begins to move
- Measured Variable: Maximum load to *just* move the pallet, F_H
- Calculate coefficient of static friction, μ_s, using equation (1)
- Perform the test in both the 48" and 40" directions

Buckling Test

This test evaluates the resistance of pallets to horizontal clamp loads, such as those encountered when pallets are handled by clamp trucks. The test is performed in a compression test machine by securing the pallet under test with the decks positioned perpendicular to the ground. The load is applied vertically by a platen 4410, as shown in Figure 44. A uniform rigid load 4412 is used. The test parameters are as follows

- Sample size / Type:2 / Full Patents
- Test Load Type: Uniform rigid
- Test Temperature(s): 23°C±2°C
- Test Duration: Instantaneous
- Platen Speed: 100mm/min
- Deformation Rate: Decreases under test load with time
- Measured Variable: Load at failure (buckling load)

Dynamic Load Tests

Drop Test

This test evaluates the cumulative effect of impacts on the pallet when it is dropped during handling. It is performed in general accordance with ASTM D1185-98a, with the test parameters being as follows:

- Sample Size / Type: 6 (3 per test temperature) / Full pallets

- Test Temperature(s): 23°C±2°C; -20°C±2°C
- Condition the pallets for 24 hours at each temperature and then test (See also section 5, Conditioning)
- Drop heights: 2m, 3, @ 23°C±2°C; 3m @ -20°C±2°C
- Test Sequence:
    - For the 23°C test, drop each pallet from 2m, and then form 3m. Perform seven (7) drops per pallet, per drop height, as follows:
        - Three on a pallet corner
        - One on adjacent 48" side along top deck edge
        - One on adjacent 48" side along bottom deck edge
        - One on adjacent 40" side along top deck edge
        - One on adjacent 40" side along bottom deck edge
    - For the -20°C test, drop each pallet once from 3m only, onto a corner
- Measured Variables:
    - Change in diagonal measurement, △ Diagonal
    - Window height, h
- Other Test Criteria:
    - No complete separation of connected components
    - No breakage which exposes blind cavities
    - No complete breakage of 1in x 1in, or more, of material

Upon conclusion of the drop tests, test each pallet to failure in an edge rack support configuration as described above and shown in Figure 34, racked across length, at 23°C±2°C, using a uniform flexible load. Record the load at failure.

Fork Tine Heel Impact - Deck Edges

This test enables the effect of multiple impacts on the pallet top deck edge which result from interaction with fork handling equipment, to be evaluated, where the forks are perpendicular to the pallet. The test is performed in general accordance with ASTM D1185-98a, the test parameters being as follows:

- Sample Size / Type: 9 (3 @ 23°C per side; 3 @ -20°C) / Full pallets
- Test Load: 700lb (including weight box)
- Test Temperature(s): 23°C±2°C; -20°C±2°C
- Condition the pallets for 24 hours at each temperature and then test
- Impact Velocity: 1.8m/s (70in/s or 4mph)
- Fork Geometry: See figure 43

- Test Sequence
  - For the 23°C test, impact each pallet on the 40" side at 1.8m/s; repeat the test on the 48" side, using new pallets
  - For the -20°C test, impact each pallet on the 40" side only, at 1.8m/s
  - Perform ten (10) impacts per pallet at each temperature
- Measured Variable: Window height, h
- Other Test Criteria:
  - No complete separation of connected components
  - No breakage which exposes blind cavities
  - No complete breakage of 1in x 1in, or more, of material

Upon conclusion of the impact tests, test each pallet to failure in an edge rack support configuration at 23°C±2°C, as described above and shown in Figure 34, as follows:

- Load Type: Uniform flexible (airbag)
- Of the six pallets that were conditioned at 23°C, test three racked across width, and three racked across length
- Of the three pallets that were conditioned at -20°C, test all racked across width
- Record the load at failure in each case

Fork Tine Angled Heel Impact - Deck Edges

The purpose of this test is to evaluate the effect of multiple impacts on the pallet top deck edge, resulting form interaction with fork handling equipment, where the forks are angled horizontally relative to the pallet.

This test shall be performed in general accordance with ASTM D1185-98a, section 9.4[9], except or as follows:

- Sample Size / Type: 9 (3 @ 23°C per side; 3 @ -20°C) / Full pallets
- Test Load: 700lb (including weight box)
- Horizontal Pallet Angle: 5° -0/+10
- Test Temperature(s): 23°C±2°C; -20°C±2°C
- Condition the pallets for 24 hours at each temperature and then test
- Impact Velocity: 1.8m/s (70in/s or 4mph)
- Fork Geometry: See figure 43
- Test Sequence:
  - For the 23°C test, test each pallet on the 40" side at 1.8m/s; repeat test on the 40" side, using new pallets

- For the -20°C test, test each pallet on the 40" side only, at 1.8m/s
- Perform ten (10) impacts per pallet at each temperature

- Measured Variable: Window height, h
- Other Test Criteria
  - No complete separation of connected components
  - No breakage which exposes blind cavities
  - No complete breakage of 1in x 1in, or more, of material

Upon conclusion of the impact tests, test each pallet to failure in an edge rack support configuration at 23°C±2°C, as described above and shown in Figure 34, as follows:

- Load Type: Uniform flexible (airbag)
- Of the six pallets that were conditioned at 23°C, test three racked across width, and three racked across length
- Of the three pallets that were conditioned at -20°C, test all racked across width
- Record the load at failure in each case

Fork Tine Tip Impact - Deck Edges

The purpose of this test is to evaluate the effect of multiple impacts on the pallet top deck edge, resulting from interaction with fork tine tips.

This test shall be performed in general accordance with ASTM D1185-98a[I], section 9.4[9], except or as follows:

- Sample Size / Type: 9 (3 @ 23°C per side; 3 @ -20°C) Full pallet
- Test Load: 700lb (Including weight box)
- Test Temperature(s): 23°C±2°C; -20°C±2°C
- Condition the pallets for 24 hours at each temperature and then test
- Impact Velocity: 1.8m/s (70in/s or 4mph)
- Fork Geometry: See figure 43
- Impact the pallet on a top deck edge with the tips of the test tines, such that the tines makes contact with the pallet at equidistant positions from the centre of the pallet
- Test Sequence:
  - For the 23°C test, test each pallet on the 40" side at 1.8m/s; repeat the test on the 48" side, using new pallets
  - For the -20°C test, test each pallet on the 40" side only, at 1.8m/s
  - Perform ten (10) impacts per pallet at each temperature
- Measured Variable: Window height, h

- Other Test Criteria:
  - No complete separation of connected components
  - No brakeage which exposes blind cavities
  - No complete breakage of 1in x 1in, or more, of material

Upon conclusion of the impact tests, test each pallet to failure in an edge rack support configuration at 23°C±2°C, as described above and shown in Figure 34, as follows:

- Load Type: Uniform flexible (airbag)
- Of the six pallets that were conditioned at 23°C, test three racked across width, and three racked across length
- Of the three pallet that were conditioned at -20°C, test all racked across width
- Record the load at failure in each case

Fork Tine Tip Impact - Spacers

The purpose of this test is to evaluate the effect of multiple impacts on the pallet spacers (blocks), resulting from interaction with fork tine tips.

This test shall be performed in general accordance with ASTM D1185-98a[I], section 9.4, except or as follows:

- Sample Size / Type: 9 (3 @ 23°C per side; 3 @ -20°C) / Full pallets
- Test Load: 700lb (Including weight box)
- Test Temperature(s): 23°C±2°C; -20°±2°C
- Condition the pallets for 24 hours at each temperature and then test
- Impact any two blocks simultaneously at, or nearest, a seam. If no seam is present, impact the blocks at the horizontal centre place of the blocks
- Impact Velocity: 1.8m/s (70in/s or 4mph)
- Fork Geometry: See figure 43
- Test Sequence:
  - For the 23°C test, test each pallet on the 40" side at 1.8m/s; repeat the test on the 48" side, using new pallets
  - For the -20°C test, test each pallet on the 40" side only, at 1.8m/s
  - Perform ten (10) impacts per pallet at each temperature
- Measured Variable: Window height, h
- Other Test Criteria
  - No complete separation of connected components
  - No breakage which exposes blind cavities

- No complete breakage of 1in x 1in, or more, of material

Upon conclusion of the impact tests, test six pallets to failure in an edge rack support configuration at 23°C±2°C, as described above and shown in Figure 34, as follows:

- Load Type: Uniform flexible (airbag)
- Of the six pallets that were conditioned at 23°C, test two racked across width, and two rack across length
- Of the three pallets that were conditioned at -20°C, test two racked across width
- Record the load at failure in each case

Additionally, test three pallets to failure in a pallet spacer compression configuration at 23°C±2°C, in accordance with section 7.1 of this Standard, as follows:

- Load Type: Uniform rigid
- Test two of the six pallets that were conditioned at 23°C
- Test one of the three pallets that were conditioned at -20°C
- Record the load at failure in each case

Vibration - Pallet Load Resonance (Durability)

This test enables the effects of vibration on the pallet at resonant frequencies to be evaluated, such as those which might result from transportation. The test is performed in general accordance with ASTM D1185-98a section 9.5, Method A, and as follows:

- Sample size / Type: 2 / Full pallets
- Test Load: 2800lb
- Test Load Type: Bulk Bag, loaded with 20lb sandbags
- Test Temperature: 23°C±2°C
- Dwell Time: One hour at the frequency that corresponds to the maximum transmissibility of the palletised load, and which is below 50Hz
- Measured Variable: All resonant frequencies between 0 and 100Hz (including the natural frequency)
- Other Test Criterion: The pallet shall not sustain any visible structural damage whatsoever

Upon conclusion of the vibration tests, test each pallet to failure in an edge rack support configuration, racked across length, at 23°C±2°C, as described above and shown in Figure 34, using a uniform flexible load. Record the load at failure.

Vibration - Pallet Transmissibility

This test evaluates the transmission of random vibration by the pallet on a unitised load, at frequencies that are normally encountered in various transportation systems. It is performed in general accordance with ASTM D1185-98a, section 9.5, Method B, and as follows:

- Sample size / Type: 2 / Full pallets
- Test Load: 600lb
- Test Load Type: RPC type 6420, 5 per layer, 3 layers high, with each RPC loaded with 2x 20lb sandbags
- Test Temperature: 23°C±2°C
- Test Duration: Per random vibration spectrum
- Random Vibration Spectrum: ASTM D4169-01e1, Truck Level 1
- Measured Variable(s):
    - Transmissibility of palletised load
    - Transmissibility of load only
- Other Test Criteria:
    - The pallet shall not sustain any visible structural damage whatsoever
    - The load shall neither sustain any damage, nor shall it collapse

Upon conclusion of the vibration tests, test each pallet to failure in an edge rack support configuration, racked across length, at 23°C±2°C, as described above and shown in Figure 34, using a uniform flexible load. Record the load at failure.

Environmental Tests

Fire Retardency

The tests which are carried out are Underwriter's Laboratory 2335 "Fire Tests of Storage Pallets", June 2001 and Factory Mutual Research Corp. Technical Memorandum "Approval Standard for Commodity Classification of Idle Plastic Pallets Class Number 4995", May 1992.

UV Resistance (Indoor Accelerated Weathering)

This test ensures that there is no performance degradation and no unacceptable colour shift as a result of exposure to the prolonged, combined, *accelerated* effects of sunlight and moisture. It is performed on test plaques for each plastic material in general accordance with ASTM D2565 - 92a "Standard Practice for Operating Xenon Arc-type Light-exposure Apparatus With and Without Water for Exposure of Plastics", ASTM 1992. The exposure procedures are detailed in ASTM G155-98

"Standard Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-Metallic Materials" ASTM 1998. The test parameters are as follows:

- Sample Type: Test plaques
- Apparatus Type: B or BH
- Minimum Irradiance: 0.35W/m^2 @ 340nm
- Exposure: 102min of light, followed by 18min of light and water spray
- Exposure Duration (Total): 7500 hours
- Exposure Type: Arizona
- Use samples that are manufactured from the same batch of raw materials for all tests
- Perform the following tests, or measurements, at time zero, and after each 1500h, 3000h, 4500h, 6000h and 7500h exposure period, using a minimum sample size of three (3) in each case:
    - Yield stress and elongation at break, per ASTM D638
    - Flexural modulus, per ASTM D790
    - Instrumented dart impact strength at 23°C±2°C, per ASTM D3763
    - L*A*B* co-ordinates (and calculate delta E), per ASTM D2244-02, via a Macbeth 7000 Colorimeter, using Hunter Lab CIELAB equations.
    - Gloss per ASTM D523-89, on a BY Gardner Glossmeter at 60° gloss angle

UV Resistance (Outdoor Weathering)

This test ensures that there is no performance degradation and no unacceptable colour shift as a result of exposure to the prolonged, *actual* effects of sunlight and moisture. It is performed on test plaques for each plastic material in general accordance with ASTM G797 "Standard Practice for Atmospheric Environmental Exposure Testing of Non-metallic Materials" ASTM 1997. Test parameters are as follows:

- Sample Type(s): Test plaques <u>and</u> full pallets
- Exposure Duration (Total): 3 Years
- Exposure Type: Test plaques – Arizona <u>and</u> Florida; Full pallets – Florida
- Use samples that are manufactured from the same batch of raw materials for all tests
- <u>For the test plaques,</u> perform the following tests, or measurements, at time zero, and after each 6-month, 12-month, 18-month, 24-month, 30-month and 36-month exposure period, using a minimum sample size of three (3) in each case:
    - Yield stress and elongation at break, per ASTM D638[III]
    - Flexural modulus, per ASTM D790[IV]
    - Instrumented dart impact strength at 23°C±2°C, per ASTM D3763[V]

- L*A*B* co-ordinates (and calculate delta E), per ASTM D2244-02[VI]
- Gloss per ASTM D523-89[VII] on a BY Gardner Glossmeter at 60° gloss angle

- For the full pallets, perform the following test sequence after each 6-month, 12-month, 18-month, 24-month, 30-month and 36-month exposure period, using a sample size of two (2):
  - Edge rack support, racked across length, at 40°C±2°C, as described above and shown in Figure 34
  - Drop test at 23°C±2°C, as described above
  - Load at failure in an edge rack support configuration, racked across length, at 23°C±2°C, as described above and shown in Figure 34, using a uniform flexible load

Fluid/Chemical Resistance

This test is performed on test plaques for each plastic material type, in general accordance with ASTM D543-95 "Standard Practice for Evaluating the Resistance of Plastics to Chemical Reagents", ASTM 2001, Practice B (Wet Patch Method) . The test parameters are as follows:

- Test Temperature 23°C±2°C
- Exposure: 7 Days per reagent
- In addition to the standard reagents, test also the following fluids: gasoline, lubricating oil and hydraulic fluid (all automotive grade)
- A reagent may be precluded from testing if data indicating compliance is provided
- Perform the following test, after the required exposure, using a minimum sample size of three (3) in each case:
  - Yield stress and elongation at break, per ASTM D638[III]
  - Flexural modulus, per ASTM D790[IV]
  - Instrumented dart impact strength at 23°C±2°C per ASTM D3763[V]

Heat Aging

This test evaluates the effects of prolonged heating on the physical performance of the pallet. It is performed on test plaques for each plastic material type in general accordance with ASTM D3045-92 "Standard Practice for Heat Aging of Plastics Without Load" ASTM 1997. The test parameters are as follows:

- Test Temperature: 60°C±2°C
- Exposure: 45 Days
- Perform the following tests, after the required exposure, using a minimum sample size of three (3) in each case:
  - Yield stress and elongation at break, per ASTM D638[III]
  - Flexural modulus, per ASTM D790[IV]

- Instrumented dart impact strength at 23°C±2°C, per ASTM D3763[V]

Water Retention

This test evaluates the ability of the pallet to self-drain after being washed. It is performed n clean, new pallets. The test parameters are as follows:

- Sample size: 3
- Test Temperature: 23°C±2°C
- Water Temperature: 23°C±5°C
- Scale Accuracy: 0.005kg
- Procedure:
  - Weigh clean pallet
  - Submerge pallet completely in water for 30 seconds
  - Remove pallet from water, right-side-up, and allow to air-dry on edge rack supports for 15 minutes
  - Re-weigh pallet
- Measured Variable(s): Pallet weight, before and after washing

Adhesion Strength of Branding Marks

This test evaluates the adhesion strength of ink or pigment-based branding marks on a new pallet. It is performed in general accordance with ASTM F1842-02 "Standard Test Method for Determining Ink or Coating Adhesion on Plastic Substrates for Membrane Switch Applications" ASTM 2002.

Further details of the specifications of the tests referred to above may be found in one or more of the following:

- ASTM D1185-98a, "Standard Test Methods for Pallets and Related Structures Employed in Materials Handling and Shipping", ASTM, 1998.
- ASTM D4169-01e1 "Standard Practice for Performance Testing of Shipping Containers and Systems", ASTM, 2001.
- D638-02a, "Standard Test Method for Tensile Properties of Plastics", ASTM, 2002.
- D790-02, "Standard Test Method for Flexural Properties of Un-reinforced and Re-inforced Plastics and Electrical Insulating Materials", ASTM, 2002.
- D3763-02, "Standard Test Method for High Speed Puncture Properties of Plastics Using Load and Displacement Sensors", ASTM, 2002.
- ASTM D2244-02, "Standard Practice for Calculation of Colour Tolerances and Colour Differences from Instrumentally Measured Colour Coordinates", ASTM, 2002.
- ASTM D523-89, "Standard Test Method for Specular Gloss", ASTM, 1999.

Claims:

1. A pallet comprising a top pallet element and a bottom pallet element, wherein each pallet element comprises a platform and a plurality of pallet feet and wherein each pallet foot comprises an interlocking section, wherein:
in an inverted configuration, the interlocking sections of the top pallet element are arranged to couple with corresponding interlocking sections of the bottom pallet element;
in a stacked configuration, with the pallet elements in substantially the same orientation, at least one pallet element forms a nested configuration when stacked on top of the other pallet element; and wherein the pallet elements are rotationally moulded from a plastics material filled with a mineral filler.

2. A pallet according to Claim 1 wherein the mineral filler comprises sand.

3. A pallet according to Claim 1 or 2 wherein the shape and/or configuration of the top pallet element is different to the shape and/or configuration of the bottom pallet element.

4. A pallet according to any preceding claim wherein, in a nested configuration, the feet of one pallet element are inserted into recesses in the top surfaces of the corresponding feet of the other pallet element.

5. A pallet according to any preceding claim wherein the bottom pallet element forms a nested configuration when stacked on top of the top pallet element.

6. A pallet according to any preceding claim wherein the top pallet element forms a nested configuration when stacked on top of the bottom pallet element.

7. A pallet according to any preceding claim wherein the pallet elements form a nested configuration when one pallet element is stacked on top of the other pallet element but wherein a gap is formed between the stacked pallet elements when the pallet elements are stacked in the reverse order.

8. A pallet according to Claim 7 wherein the gap formed between the stacked pallet elements is greater than around 20mm, preferably greater than around 40mm and preferably greater than around 50mm.

9. A pallet according to any preceding claim wherein the platform of the bottom pallet element comprises at least one aperture.

10. A pallet according to any preceding claim wherein the feet of the pallet elements are arranged to enable the blades of a forklift truck to engage the pallet from any one of four directions.

11. A pallet according to any preceding claim wherein the interlocking sections comprise male or female interlocking sections and wherein, in an inverted configuration, male interlocking sections on one pallet element couple with corresponding female interlocking sections on the other pallet element.

12. A pallet according to any preceding claim wherein the interlocking sections of the top pallet element comprise male interlocking sections.

13. A pallet according to any preceding claim wherein the interlocking sections of the bottom pallet element comprise female interlocking sections.

14. A pallet according to any preceding claim wherein at least a portion of each pallet element comprises an outer skin layer.

15. A pallet according to Claim 14 wherein at least a portion of each pallet element comprises an inner layer having a different composition to the outer skin layer.

16. A pallet according to Claim 15 wherein the inner layer comprises a foamed inner layer.

17. A pallet according to any preceding claim wherein the pallet element further comprises a remotely readable tag, preferably an RFID tag or a bar code.

18. A pallet according to any preceding claim wherein the platform of the top pallet element comprises a substantially continuous surface.

19. A pallet according to any preceding claim wherein the platform of each pallet element comprises a textured surface.

20. A pallet according to any preceding claim wherein the feet of the pallet elements are tapered.

21. A pallet according to any preceding claim wherein the interlocking sections of the feet of the pallet elements are arranged so that, on rotation of the bottom pallet element about an axis through the

plane of the platform of the bottom pallet element, a male configuration of interlocking sections on the bottom pallet element mates with a female configuration of interlocking sections on the top pallet element and vice versa.

22. A pallet according to any preceding claim wherein a male interlocking section of a foot comprises a protruding element and a corresponding female interlocking section of a foot comprises a hollow section, wherein the hollow section is sized to accommodate a protruding element.

23. A pallet according to any preceding claim wherein each pallet element is rotationally moulded substantially in one piece.

24. A pallet element comprising a platform having an upper surface and a lower surface and a plurality of feet depending from the lower surface of the platform and wherein:
a single pallet element provides a single-sided pallet having feet of a height sufficient to allow lifting by a forklift truck;
a first said pallet element is arranged to couple to a second said pallet element to provide a double-sided pallet having a total height less than double the height of a single pallet element.

25. A pallet element according to Claim 24 wherein the first and the second pallet elements couple to provide a double-sided pallet wherein the feet of both the first and the second pallet are arranged between the platforms of the pallet elements.

26. A pallet element according to Claim 25 or 26 wherein the pallet elements are arranged to couple on presenting opposed elements appropriately located without further fixings or adhesives.

27. A pallet element according to any of claims 24 to 26 wherein the height of single pallet element is substantially equal to the height of a standard pallet.

28. A pallet element according to any of claims 24 to 27 wherein the height of a single pallet element is at least around 100mm.

29. A pallet element according to any of claims 24 to 28 wherein in a double-sided pallet, the feet of the first pallet element interleave at least partially with the feet of the second pallet element.

30. A pallet element according to any of claims 24 to 29 wherein the height of a double-sided pallet is substantially equal to the height of a single-sided pallet.

31. A pallet element according to any of claims 24 to 30 wherein the height of a double-sided pallet is substantially equal to the height of a standard pallet.

32. A pallet element according to any of claims 24 to 31 wherein the height of a double-sided pallet is less than around 200mm.

33. A pallet element according to any of claims 24 to 32 wherein the difference in height between a double-sided pallet and a single-sided pallet is substantially equal to the height of the platform of a pallet element.

34. A pallet element according to any of claims 24 to 33 wherein the difference in height between a double-sided pallet and a single-sided pallet is less than the height of the platform of a pallet element.

35. A pallet element according to any of claims 24 to 34 wherein the height of the feet supporting the platform of a single-sided pallet is substantially equal to the spacing between platforms of a double-sided pallet.

36. A pallet element according to any of claims 24 to 35 wherein the first pallet element is coupled to the second pallet element by inserting the feet of at least one pallet element into recesses formed in the lower surface of the platform of the other pallet element.

37. A pallet element according to any of claims 24 to 36 wherein the recesses in the lower surface of the platform comprise deformable teeth, wherein the deformable teeth latch around the feet of the opposing pallet element to retain the feet in the recesses.

38. A pallet element according to any of Claims 24 to 35 wherein the feet of each pallet element comprise foot elements, the foot elements of each foot being arranged to interleave with corresponding foot elements in the opposing foot.

39. A pallet element according to any of claims 24 to 38 wherein at least one foot is arranged substantially at each corner of the platform.

40. A pallet element according to any of claims 24 to 39 wherein at least one foot is arranged substantially at the centre of the platform.

41. A pallet element according to any of claims 24 to 40 wherein at least one foot is arranged substantially at the centre of each edge of the platform.

42. A pallet element according to any of claims 24 to 41 wherein the feet of the pallet elements are arranged so that, on rotation of one pallet element about an axis through the plane of the platform of the pallet, a male configuration of feet on one pallet element mates with a female configuration of feet on the opposing pallet element.

43. A pallet element according to any of claims 24 to 42 wherein at least some of the feet of the pallet are arranged on the platform rotationally asymmetrically about at least one axis of rotation passing through the centre of the plane of the platform of the pallet and parallel to an edge of the pallet.

44. A pallet element according to Claim 42 or 43 wherein one male configuration of feet comprises a single foot and a corresponding female configuration of feet comprises two feet separated by a gap, wherein the gap is sized to accommodate a single foot.

45. A pallet element according to any of claims 24 to 44 wherein the pallet element is substantially rectangular.

46. A pallet element according to any of claims 24 to 45 wherein, when one pallet element is rotated in an axis in the plane of the pallet platform and perpendicular to the elongate axis of the pallet platform, the feet of the pallet element interleave with the feet of a second pallet element.

47. A pallet element according to any of claims 24 to 46 wherein, when the first pallet is rotated, the feet of the first pallet are offset relative to the feet of the second pallet.

48. A pallet element according to any of Claims 42 to 47 wherein a male configuration of feet comprises an odd number of feet and a female configuration of feet comprises an even number of feet.

49. A pallet element according to any of Claims 42 to 48 wherein the feet in the male configuration and the feet in the female configuration are mutually offset when a first pallet element is rotated and positioned over a second pallet element so that the platforms are aligned.

50. A pallet element according to any of Claims 42 to 49 wherein feet in the corners of the pallet comprise male or female configurations of feet and feet in the along the centre lines of the pallet are mutually offset from the centre.

51. A pallet element according to any of claims 24 to 50 wherein the pallet elements are rotationally moulded.

52. A pallet element according to any of claims 24 to 51 wherein each pallet element is rotationally moulded substantially in one piece.

53. A pallet element according to any of claims 24 to 52 wherein the pallet elements are manufactured substantially from a filled plastics material.

54. A pallet element according to any of claims 24 to 53 wherein the filler comprises a mineral filler material.

55. A pallet element according to any of claims 24 to 54 wherein the feet of each pallet element are formed integrally with the platform of the pallet element.

56. A pallet element according to any of claims 24 to 55 wherein the feet are tapered from a maximum width at the platform of the pallet element.

57. A pallet element according to Claim 56 wherein at least one side of at least one tapered foot of the pallet is concave.

58. A pallet element according to any of claims 24 to 57 wherein recesses are provided in the upper surface of the platform of the pallet.

59. A pallet element according to Claim 58 wherein the recesses in the upper surface correspond to the position of the feet of a pallet element.

60. A pallet element according to any of claims 24 to 59 wherein at least one foot is hollow.

61. A pallet element according to any of Claims 58 to 60 wherein the recesses in the upper surface extend through the platform from the upper surface of the pallet element into the feet.

62. A pallet element according to any of claims 24 to 61 wherein pallet elements form a nested configuration when stacked on top of each other in the same orientation.

63. A pallet element according to any of claims 24 to 62 wherein, in a nested configuration, the feet of one pallet element are inserted into recesses in the corresponding feet of a second pallet element.

64. A pallet element according to any of claims 24 to 63 wherein the feet are arranged to enable the blades of a forklift truck to engage the pallet from any one of four directions.

65. A pallet element according to any of claims 24 to 64 wherein at least a portion of the pallet element comprises an outer skin layer.

66. A pallet element according to Claim 65 wherein at least a portion of the pallet element comprises an inner layer having a different composition to the outer skin layer.

67. A pallet element according to Claim 66 wherein the inner layer comprises a foaming agent.

68. A pallet element according to any of claims 24 to 67 wherein the pallet element further comprises a remotely readable tag, preferably an RFID tag.

69. A pallet element according to any of claims 24 to 68 wherein the platform of the pallet element comprises a substantially continuous surface.

70. A pallet element according to any of claims 24 to 69 wherein the platform of the pallet element comprises a textured surface.

71. A method of assembling a double-sided pallet using two pallet elements, each pallet element comprising a platform and a plurality of feet depending from the platform, the method comprising:

rotating the first pallet element about an axis in the plane of the pallet platform;

arranging the second pallet element on top of the first pallet element so that the feet of both of the pallet elements lie between the platforms of the pallet elements and the feet of the pallet elements are interleaved;

coupling the second pallet element to the first pallet element.

72. A method according to Claim 71 wherein step of coupling comprises applying pressure to the pallet elements.

73. A method according to Claim 72 wherein applying pressure comprises applying a force of less than around 1000N, preferably less than around 500N, or applying an impact from a hammer of less than around 10Ns.

74. A method according to any of Claims 71 to 73 wherein coupling comprises coupling the pallet elements without adhesives or fixings.

75. A method of manufacturing a plurality of pallets comprising:
inserting a feedstock comprising a filled plastics material into a mould;
rotating and heating the mould to rotationally mould a plurality of pallets;
releasing the plurality of pallets from the mould
separating the moulded plurality of pallets into single pallets.

76. A method according to Claim 75 further comprising inserting a second feedstock into the mould to form an inner layer within the pallet.

77. A method according to Claim 76 wherein the second feedstock includes a foaming agent to form a foamed inner layer.

78. A method according to any of Claims 75 to 77 wherein separating the moulded plurality of pallets comprises punching or cutting the pallets out of a sheet of moulded pallets.

79. A method of distributing pallets comprising arranging layers of pallets in a nested configuration in a container, shipping the container to a predetermined destination, removing the pallets from the container.

80. A method according to Claim 79 wherein the pallets comprise pallet elements according to the aspect described above or any of its preferred features.

81. A method according to Claim 78 or 79 wherein the pallets and the container are rotationally moulded.

82. A method according to any of Claims 78 to 81 wherein the layers of pallets are provided in sheets and the method further comprises cutting the sheets of pallets into individual pallets.

83. A rotationally-moulded load-carrying apparatus for carrying a load of at least 50 kilograms, wherein the apparatus is manufactured substantially from a filled plastics material comprising:
at least 10% by weight of a polymer;
at least 10% by weight of a mineral filler material.

84. Apparatus according to Claim 83 wherein the mineral filler material comprises a silicate material, preferably sand.

85. Apparatus according to Claim 83 wherein the mineral filler material comprises a carbonate material, preferably calcium carbonate.

86 Apparatus according to Claim 83, 84 or 85 wherein the polymer comprises polyethylene, preferably wherein the polymer comprises High Density Polyethylene (HDPE).

87. Apparatus according to any of Claims 83 to 86 wherein the material comprises at least 25% by weight filler.

88. Apparatus according to any of Claims 83 to 87 wherein the material comprises at least 25% by weight polymer.

89. Apparatus according to any of Claims 83 to 88 wherein the material comprises from about 30% to about 70% by weight polymer and from about 70% to about 30% by weight filler.

90. Apparatus according to any of Claims 83 to 89 wherein the filled plastics material further comprises a unifier.

91. Apparatus according to Claim 90 wherein the filled plastics material comprises at least about 0.1% by weight unifier.

92. Apparatus according to Claim 90 or 91 wherein the filled plastics material comprises less than about 10% by weight unifier.

93. Apparatus according to any of Claims 90 to 92 wherein the filled plastics material comprises at least about 0.25% by weight unifier.

94. Apparatus according to any of Claims 90 to 93 wherein the filled plastics material comprises less than about 5% by weight unifier.

95. Apparatus according to any of Claims 90 to 94 wherein the unifier is pre-mixed with the filler.

96. Apparatus according to any of claims 90 to 95 wherein the unifier comprises an internal lubricant.

97. Apparatus according to Claim 96 wherein the internal lubricant comprises a fatty acid amide.

98. Apparatus according to Claim 97 wherein the internal lubricant comprises a straight or branched C_{12}-C_{24} fatty acid amide.

99. Apparatus according to any of Claims 96 to 98 wherein the internal lubricant comprises steramide.

100. Apparatus according to any of Claims 96 to 99 wherein the unifier further comprises an external lubricant, preferably wherein the external lubricant comprises a stearate.

101. Apparatus according to any of Claims 96 to 100 wherein the unifier comprises less than 20% by weight internal lubricant.

102. Apparatus according to any of Claims 96 to 101 wherein the unifier comprises about 10% by weight internal lubricant.

103. Apparatus according to any of Claims 83 to 102 wherein the filler comprises at least one of:
a silicate material, preferably sand;
ash;
a carbonate material, preferably calcium carbonate;
a salt, preferably sodium chloride.

104. Apparatus according to any of Claims 83 to 103 wherein the apparatus is rotationally moulded substantially in one piece.

105. Apparatus according to any of Claims 83 to 104 wherein the filler comprises a light-coloured material.

106. Apparatus according to any of Claims 83 to 105 wherein the apparatus comprises a pallet., preferably wherein the pallet is moulded substantially in one piece.

107. Apparatus according to Claim 106 wherein the pallet comprises a platform and a plurality of feet depending from the platform.

108. Apparatus according to Claim 107 wherein the feet of the pallet are regularly spaced over the lower surface of the platform.

109. Apparatus according to Claim 107 or 108 wherein the feet are arranged to enable lifting equipment to engage the pallet from any one of four directions.

110. Apparatus according to any of Claims 107 to 109 wherein at least one foot is arranged substantially at each corner of the platform of the pallet.

111. Apparatus according to any of Claims 107 to 110 wherein at least one foot is arranged substantially at the centre of the platform of the pallet.

112. Apparatus according to any of Claims 107 to 111 wherein at least one foot is arranged substantially at the centre of each edge of the platform of the pallet.

113. Apparatus according to any of Claims 107 to 112 wherein the feet of the pallet are moulded integrally with the platform.

114. Apparatus according to any of Claims 107 to 113 wherein each foot has a recess in the lower surface of the foot.

115. Apparatus according to any of Claims 107 to 114 wherein the pallet comprises an outer skin layer having an upper surface and a lower surface.

116. Apparatus according to Claim 115 wherein the upper and lower surfaces of the outer skin layer are arranged to abut each other over at least a portion of the pallet surface.

117. Apparatus according to Claim 115 or 116 wherein the pallet further comprises an inner layer having a different composition to the outer skin layer.

118. Apparatus according to Claim 117 wherein the inner layer comprises a foaming agent.

119. Apparatus according to Claim 117 or 118 wherein the inner layer comprises at least 40% by weight of a filler.

120. Apparatus according to any of Claims 107 to 119 wherein the pallet has a length of at least 800mm.

121. Apparatus according to any of Claims 83 to 120 wherein the apparatus comprises a plurality of layers.

122. Apparatus according to Claim 121 wherein the composition of the filled plastics material differs between the layers.

123. Apparatus according to Claim 121 or 122 wherein the composition of a first layer of the apparatus is optimised to provide an outer skin layer.

124. Apparatus according to Claim 123 wherein the outer skin layer comprises more than about 50% by weight polymer.

125. Apparatus according to Claim 123 or 124 wherein the outer skin layer comprises about 60% by weight polymer.

126. Apparatus according to any of Claims 121 to 125 wherein the composition of a second layer of the apparatus is optimised to provide an inner layer.

127. Apparatus according to Claim 126 wherein the inner layer comprises a polymer.

128. Apparatus according to Claim 126 or 127 wherein the inner layer comprises a polymer and a filler.

129. Apparatus according to Claim 128 wherein the inner layer comprises more than about 30% by weight filler.

130. Apparatus according to Claim 128 or 129 wherein the inner layer comprises more than about 50% by weight filler.

131. Apparatus according to any of Claims 128 to 130 wherein the inner layer comprises about 60% by weight filler.

132. Apparatus according to any of Claims 128 to 131 wherein the inner layer comprises a greater amount of filler by weight than the outer layer.

133. Apparatus according to any of Claims 128 to 132 wherein the inner layer comprises a foaming agent, preferably wherein the foam layer is about 50% foamed.

134. Apparatus according to any of Claims 83 to 133 wherein the filled plastics material further comprises a pigment.

135. Apparatus according to any of Claims 83 to 134 wherein the apparatus incorporates a remotely readable ID tag, preferably an RFID tag.

136. Apparatus according to Claim 135 wherein the ID tag is moulded into the surface of the apparatus.

137. A method of manufacturing apparatus for storage or transportation of loads greater than about 50 kilograms, the method comprising rotationally moulding the apparatus from a filled plastics material comprising a polymer, a filler and a unifier.

138. A method of rotationally moulding a product from a filled plastics material comprising:
providing a mould for the product defining a void corresponding to at least a portion of the required shape of the product;
loading a first feedstock having a first composition comprising a polymer and at least 10% by weight of a mineral filler into the mould;
heating the mould;
rotating and/or rocking the mould about at least two axes to coat the internal walls of the mould with a layer of the first feedstock;
cooling the mould;

releasing the product from the mould.

139. A method according to Claim 138 further comprising providing heating means adjacent to the walls of the mould and heating the mould using the heating means.

140. A method according to Claim 138 or 139 further comprising providing cooling means adjacent to the walls of the mould and cooling the mould using the cooling means.

141. A method according to any of Claims 138 to 140 wherein the heating means comprises a plurality of burners.

142. A method according to any of Claims 138 to 141 wherein the cooling means comprises at least one supply of water.

143. A method according to any of Claims 138 to 142 wherein the mould is a generally elongate mould and wherein the method comprises rotating the mould about a first axis substantially parallel to the axis of elongation of the mould and rocking the mould about a second axis substantially orthogonal to the first axis.

144. A method according to any of Claims 138 to 143 wherein rocking the mould comprises rocking the mould to a maximum angle of less than about 30° from the horizontal.

145. A method according to any of Claims 138 to 144 wherein rocking the mould comprises rocking the mould at a rate of less than about 6 rocking cycles per minute.

146. A method according to any of Claims 138 to 145 wherein rotating the mould comprises rotating the mould at a rate of less than about 10 revolutions per minute.

147. A method according to any of Claims 138 to 146 wherein the mould comprises an inner mould portion and an outer mould portion, wherein the inner mould portion is positioned within the outer mould portion and wherein the first feedstock is inserted between the outer mould portion and the inner mould portion.

148. A method according to Claim 147 further comprising providing heating means within the inner mould portion.

149. A method according to any of Claims 138 to 148 further comprising maintaining the heating means at a substantially constant distance from the walls of the outer mould portion as the mould is rotated.

150. A method according to any of Claims 138 to 149 further comprising, before cooling the mould:
loading a second feedstock having a second composition into the mould;
rotating the mould to form a second layer of the second feedstock.

151. A method according to any of Claims 138 to 150 wherein the composition of the first layer is optimised to provide an outer skin layer.

152. A method according to Claim 150 or 151 wherein the composition of the second layer is optimised to provide an inner layer.

153. A method according to any of Claims 150 to 152 wherein the second feedstock comprises a foaming agent.

154. A method according to any of Claims 150 to 153 wherein the second feedstock comprises a higher proportion of filler than the first feedstock.

155. A method according to any of Claims 138 to 154 wherein the product comprises at least one of: a freight container, a pallet, a cable reel or a panel.

156. A method according to any of Claims 138 to 155 further comprising positioning elements of the product within the mould before the feedstock is inserted and over-moulding the elements into the product.

157. A method according to Claim 156 wherein the product comprises a freight container and wherein the elements comprise one or more of:
a metal frame;
door securing means;
strengthening elements; or
corner lifting elements.

158. A method according to any of Claims 138 to 157 wherein the product is moulded substantially in one piece.

159. A method according to any of Claims 138 to 158 wherein releasing the product from the outer mould portion comprises moving the walls of the outer mould portion apart and away from the moulded product.

160. A filled plastics material comprising:
a polymer;
at least 10% by weight of a mineral filler;
a unifier comprising stearate.

161. A filled plastics material according to Claim 160 wherein the unifier further comprises an internal lubricant, preferably steramide.

162. A filled plastics material according to Claim 161 wherein the steramide comprises Chrodamide S Powder.

163. A filled plastics material according to any of Claims 160 to 162 wherein the stearate comprises Calcium Stearate.

164. A filled plastics material according to any of Claims 160 to 163 wherein the unifier comprises more than 5% by weight steramide.

165. A filled plastics material according to any of Claims 160 to 164 wherein the unifier comprises about 10% by weight steramide.

166. A filled plastics material according to any of Claims 160 to 165 wherein the unifier comprises more than 80% by weight stearate.

167. A filled plastics material according to any of Claims 160 to 166 wherein the unifier comprises about 90% by weight stearate.

168. A filled plastics material according to any of Claims 160 to 167 wherein the polymer comprises polyethylene.

169. A filled plastics material according to any of Claims 160 to 168 wherein the polymer comprises High Density Polyethylene (HDPE).

170. A filled plastics material according to any of Claims 160 to 169 wherein the filler comprises at least one of:
a silicate material, preferably sand;
ash;
a carbonate material, preferably calcium carbonate;
a salt, preferably sodium chloride.

171. A filled plastics material according to any of Claims 160 to 170 wherein the filled plastics material comprises at least 0.5% by weight unifier.

172. A filled plastics material according to any of Claims 160 to 171 wherein the filled plastics material comprises about 1% by weight unifier.

173. Apparatus for rotationally moulding, from a filled plastics material, a load-carrying apparatus for carrying a load of at least 50 kilograms, the apparatus comprising:
a mould defining a void corresponding to at least a portion of the required shape of the product;
means for receiving a first feedstock comprising a filled plastics material comprising a polymer and at least 10% by weight of a mineral filler;
heating means;
cooling means;
means for rotating and/or rocking the mould about at least two axes.

174. Apparatus according to Claim 173 wherein the heating means are provided adjacent to the walls of the mould.

175. Apparatus according to Claim 173 or 174 wherein the cooling means are provided adjacent to the walls of the mould.

176. Apparatus according to any of Claims 173 to 175 wherein the mould is a generally elongate mould and wherein the apparatus further comprises means for rotating the mould about a first axis substantially parallel to the axis of elongation of the mould and means for rocking the mould about a second axis substantially orthogonal to the first axis.

177. Apparatus according to any of Claims 173 to 176 wherein the mould comprises an inner mould portion and an outer mould portion, wherein the inner mould portion is positioned within the outer mould portion and wherein the first feedstock is inserted between the outer mould portion and the inner mould portion.

178. Apparatus according to any of Claims 173 to 177 further comprising heating means within the mould.

179. Apparatus according to any of Claims 173 to 178 further comprising means for maintaining the heating means at a substantially constant distance from the mould.

180. Apparatus according to any of Claims 173 to 179 wherein the mould has a length of at least 5m.

181. Apparatus according to any of Claims 173 to 180 wherein the mould has a length of at least 10m.

182. Apparatus according to any of Claims 173 to 181 wherein the apparatus is mounted over a pit and wherein at least one end of the mould is rocked into the pit.

183. Apparatus according to any of Claims 173 to 182 wherein the means for receiving the feedstock comprises a series of apertures in the outer mould portion.

184. Apparatus according to Claim 183 wherein the series of apertures is formed along at least one edge of the outer mould portion.

185. Apparatus according to Claim 183 or 184 to wherein the series of apertures is covered by at least one sliding gate valve.

186. Apparatus according to any of Claims 183 to 185 wherein the internal surface of the sliding gate valve is coated in a non-stick material.

187. Apparatus according to any of Claims 151 to 164 further comprising at least one hopper for storing the feedstock.

188. Apparatus according to Claim 187 wherein the hopper comprises dispensing means for dispensing a predetermined amount of the feedstock, wherein the predetermined amount comprises the amount of feedstock required to rotationally mould at least one load-carrying apparatus.

189. Apparatus according to any of Claims 173 to 188 further comprising filling means for loading the mould with a predetermined amount of the feedstock.

190. Apparatus according to Claim 189 wherein the filling means comprises means for filling the feedstock via a series of apertures in the outer mould portion.

191. Apparatus according to Claim 190 wherein the means for filling the feedstock comprises at least one bucket having a series of apertures corresponding to the series of apertures in the outer mould portion.

192. Apparatus according to Claim 191 wherein the bucket comprises a telescopic bucket having an adjustable length.

193. Apparatus according to any of Claims 173 to 192 wherein the heating means comprises at least one burner.

194. Apparatus according to any of Claims 173 to 193 wherein the cooling means comprises a supply of water.

195. A unifier for promoting binding and dispersion of a mineral filler and a polymer, wherein the unifier comprises a fatty acid amide.

196. A unifier according to Claim 195 wherein the fatty acid amide comprises a straight or branched C12-C24 fatty acid amide.

197. A unifier according to Claim 195 or 196 wherein the unifier comprises steramide.

198. A unifier according to any of Claims 195 to 197 further comprising an external lubricant, preferably wherein the external lubricant comprises a stearate.

199. A unifier according to Claim 198 comprising more than 80% by weight external lubricant.

200. A unifier according to Claim 198 or 199 comprising about 90% by weight external lubricant.

201. A rotationally-moulded load-carrying apparatus comprising:
at least 10% by weight HDPE;
at least 10% by weight of a filler comprising sand;
a unifier comprising a fatty acid amide;

wherein the load-carrying apparatus comprises an inner layer and an outer layer, the layers having different compositions.

202. Apparatus according to Claim 201, wherein the apparatus comprises a pallet having a length of at least about 800mm.

203. Apparatus according to Claim 201 to 202 wherein the inner layer comprises a foamed layer.

204. A pallet according to any of claims 220 to 246 comprising a plurality of pallet elements according to any of claims 24 to 71.

205. A pallet according to any of claims 1 to 23 or 220 to 246 manufactured by the method of any of claims 71 to 74.

206. A plurality of pallets according to any of claims 1 to 23 or 220 to 246 manufactured according to the method of any of claims 74 to 77.

207. A pallet according to any of claims 1 to 23 or 220 to 246 manufactured using the apparatus of any of claims 83 to 137.

208. A pallet according to any of claims 1 to 23 or 220 to 246 manufactured by the method of any of claims 138 to 157 or claim 159.

209. A pallet according to any of claims 1 to 23 or 220 to 246 made of a material according to any of claims 160 to 173.

210. A pallet according to any of claims 1 to 23 or 220 to 246 manufactured using the apparatus of any of claims 174 to 194.

211. A pallet according to any of claims 1 to 23 or 220 to 246 comprising a unifier according to any of claims 195 to 200.

212. A pallet according to any of claims 1 to 23 or 220 to 246 and any of claims 201 to 203.

213. A pallet substantially as hereinbefore described and as shown in the accompanying drawings.

214. Apparatus substantially as any one described herein or as illustrated in any of Figs. 1 to 27.

215. A method substantially as any one described herein with reference to any of Figs. 1 to 27.

216. A filled plastics material substantially any one as described herein.

217. A pallet, a mould or an assembly station substantially as any one herein described.

218. A pallet substantially as hereinbefore described and as shown in Figures 9a, 9b, 10 or Figures 17 to 20 or 24.

219. A pallet or pallet element substantially as hereinbefore described and as shown in Figures 28 to 45 or Figures 46 to 58.

220. A pallet made of a plastics material capable of meeting, or exceeding, any, some or all of the test criteria hereinbefore described.

221. A rotationally moulded pallet manufactured substantially from a filled plastics material, wherein the pallet has:
a length of greater than around 1000mm and less than around 1500mm;
a mass of less than around 30kg;
a maximum load carrying capability of greater than around 1000kg.

222. A pallet according to Claim 221 wherein the mass of the pallet is less than around 25kg, preferably around 23kg.

223. A pallet according to Claim 221 or 222 wherein the maximum load carrying capability of the pallet is greater than around 1100kg, preferably around 1250kg.

224. A pallet according to any of Claims 220 to 223 further comprising an ultraviolet stabiliser.

225. A pallet according to any of Claims 220 to 224, wherein the pallet has an opaque and/or a non-reflective surface.

226. A pallet according to any of Claims 220 to 225, wherein the pallet comprises a top deck, a bottom deck, and at least one spacer positioned between the top deck and the bottom deck.

227. A pallet according to Claim 226 wherein the top of the top deck, the top of the bottom deck and the interior of the at least one spacer are surface textured to around 15μm to 20μm.

228. A pallet according to any of Claims 220 to 227 comprising an indelible marking.

229. A pallet according to any of Claims 220 to 228, wherein the pallet is marked with a code.

230. A pallet according to any of Claims 220 to 229 wherein the pallet comprises recyclable materials.

231. A pallet according to any of Claims 220 to 230 having a damage rate per trip of less than or equal to 0.25%.

232. A pallet according to any of Claims 220 to 231, wherein the pallet does not contain sufficient amounts of residual monomers, residual solvents or other volatile substances to contaminate products under load.

233. A pallet according to any of Claims 220 to 232, wherein the pallet is compatible with fat-containing foods.

234. A pallet according to any of Claims 220 to 233 wherein the pallet does not emit or absorb noxious or toxic substances, or strong odours.

235. A pallet according to any of Claims 220 to 234 wherein the pallet comprises a material which is non-porous and non-hydroscopic.

236. A pallet according to any of Claims 220 to 235 wherein the pallet has anti-static properties.

237. A pallet according to any of Claims 220 to 236 wherein the pallet is designed to allow circulation of air through the pallet.

238. A pallet according to any of Claims 220 to 237, wherein the pallet comprises a top deck and wherein the top deck comprises through holes which are tapered so that the smaller openings are at the top of the top deck and the larger openings are at the bottom of the top deck.

239. A pallet according to any of Claims 220 to 238 wherein the pallet comprises a top deck and a bottom deck and wherein all of the internal radii on the bottom of the top deck and the bottom of the bottom deck have a minimum radius of approximately 3.175 mm.

240. A pallet according to any of Claims 220 to 239, wherein the pallet comprises a top deck and a bottom deck and wherein the pallet has a minimum slope of approximately 3° across the top of the bottom deck.

241. A pallet according to any of Claims 220 to 240 which, after being rinsed with water at 22°C ±2°C, and allowed to air-dry at 22°C ±2°C, retains no more than approximately 20g of water.

242. A pallet according to any of Claims 220 to 241 further comprising a means of identification.

243. A pallet according to Claim 242 in which the means of identification comprises a RFID tag.

244. A pallet according to Claim 242 in which the means of identification comprises a barcode.

245. A pallet according to any of Claims 220 to 244 further comprising a lug suitable for securing a stretchwrap leader to.

246. A pallet according to any of Claims 220 to 245 having a bottom deck coverage of more than 55%.

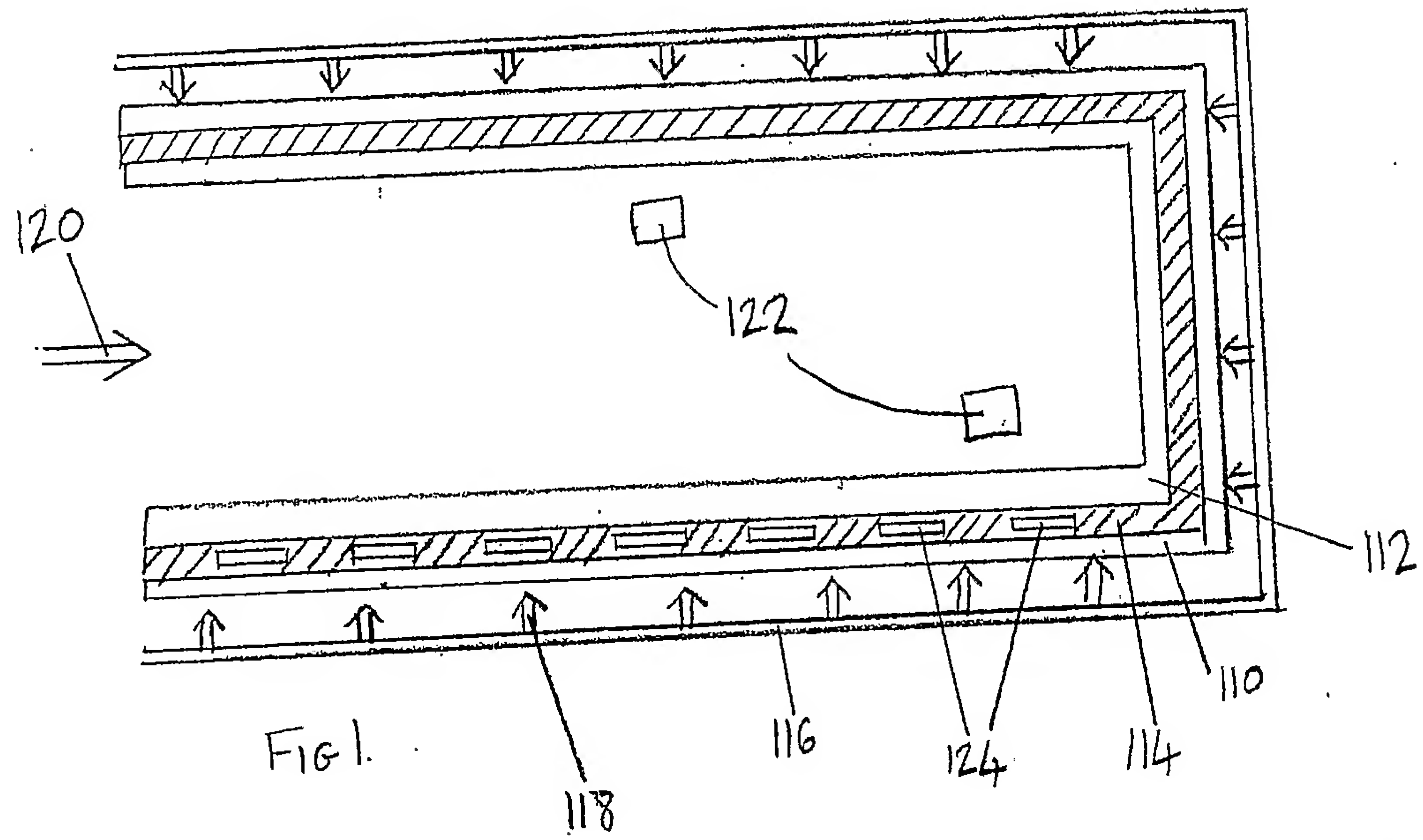

FIG 1.

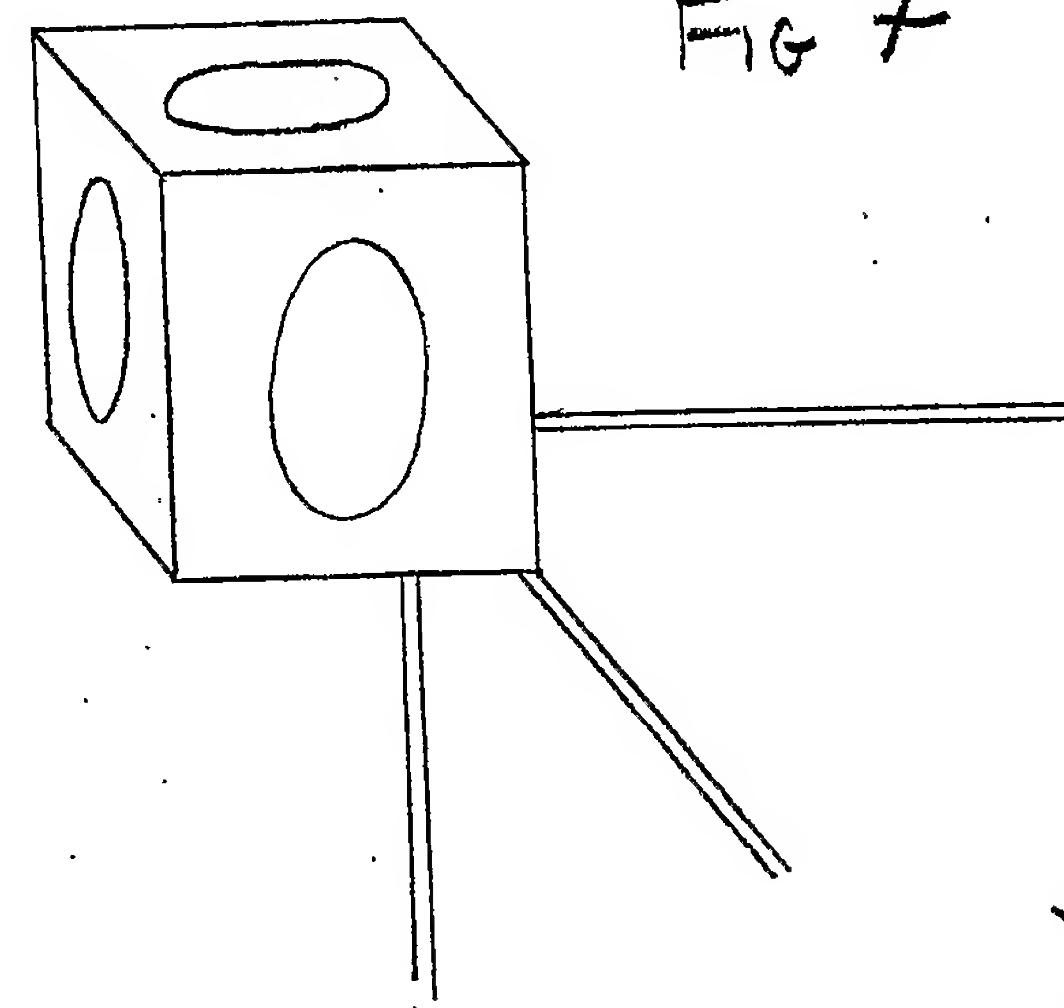

FIG 7

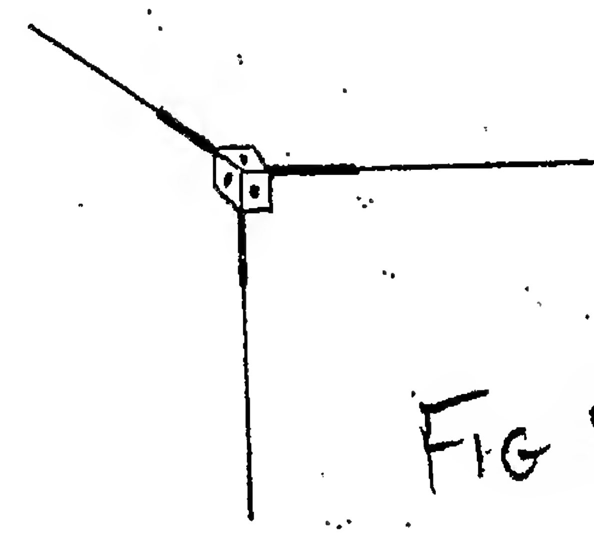

FIG 8

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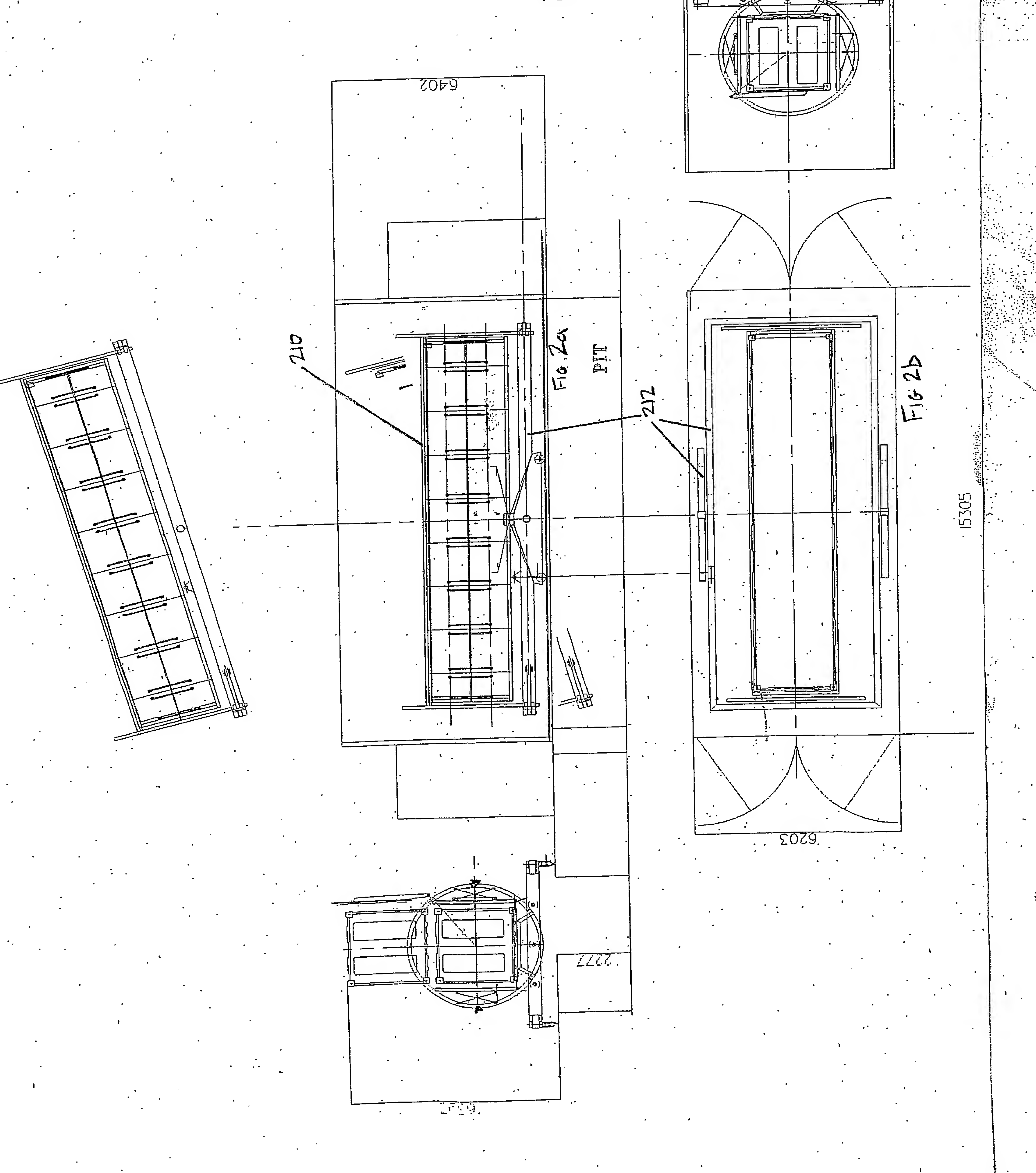

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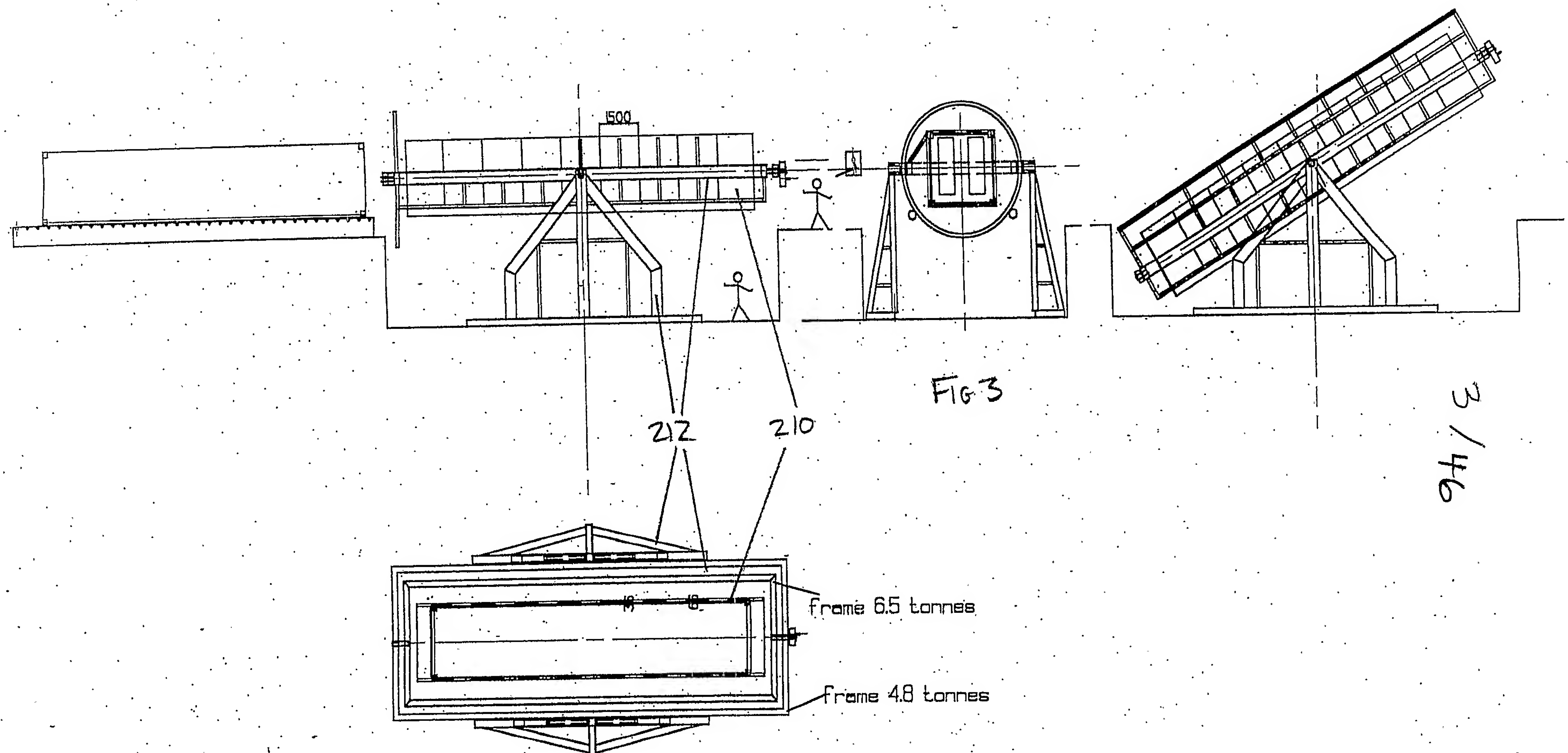


FIG 3

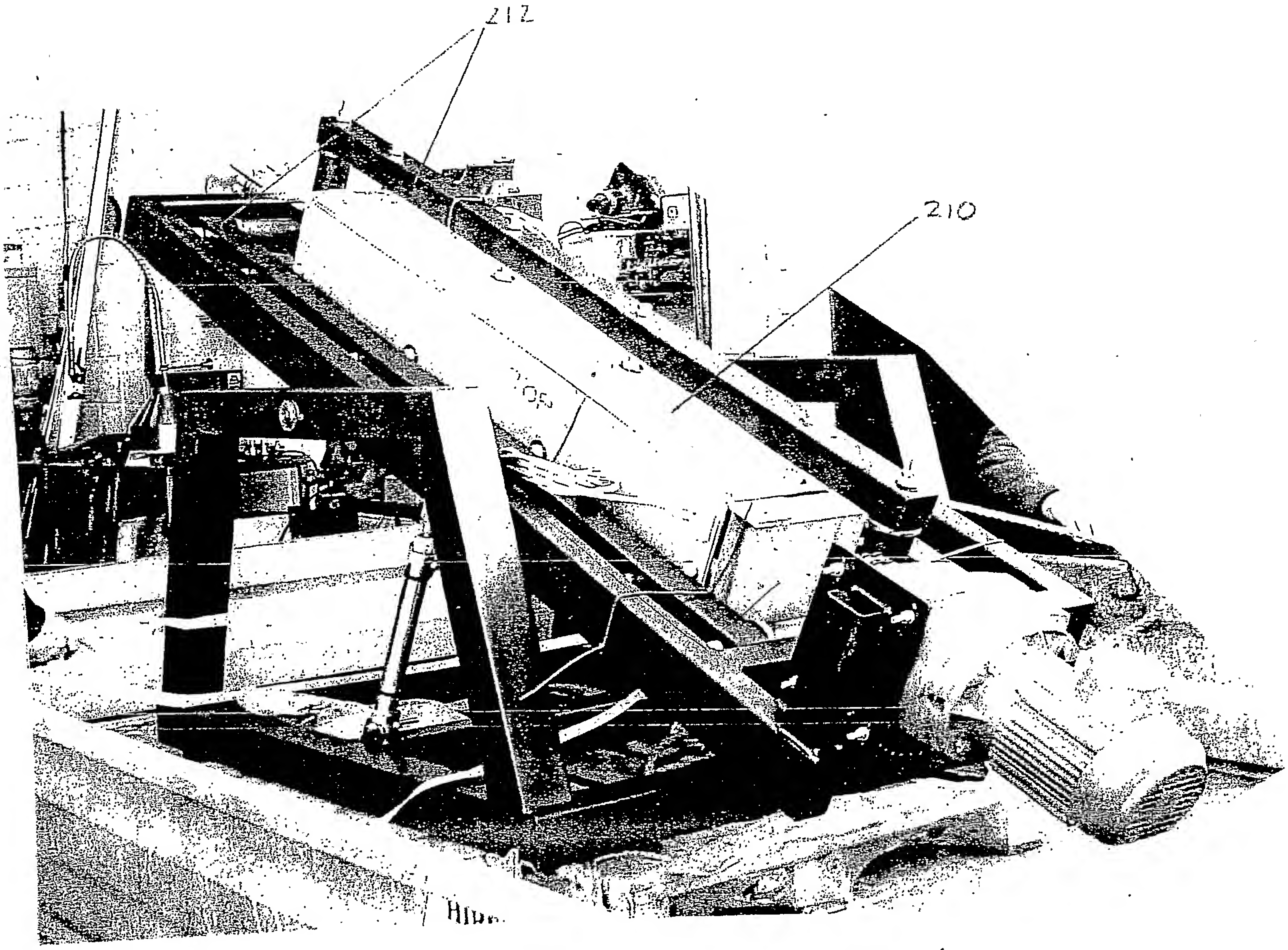


FIG 4

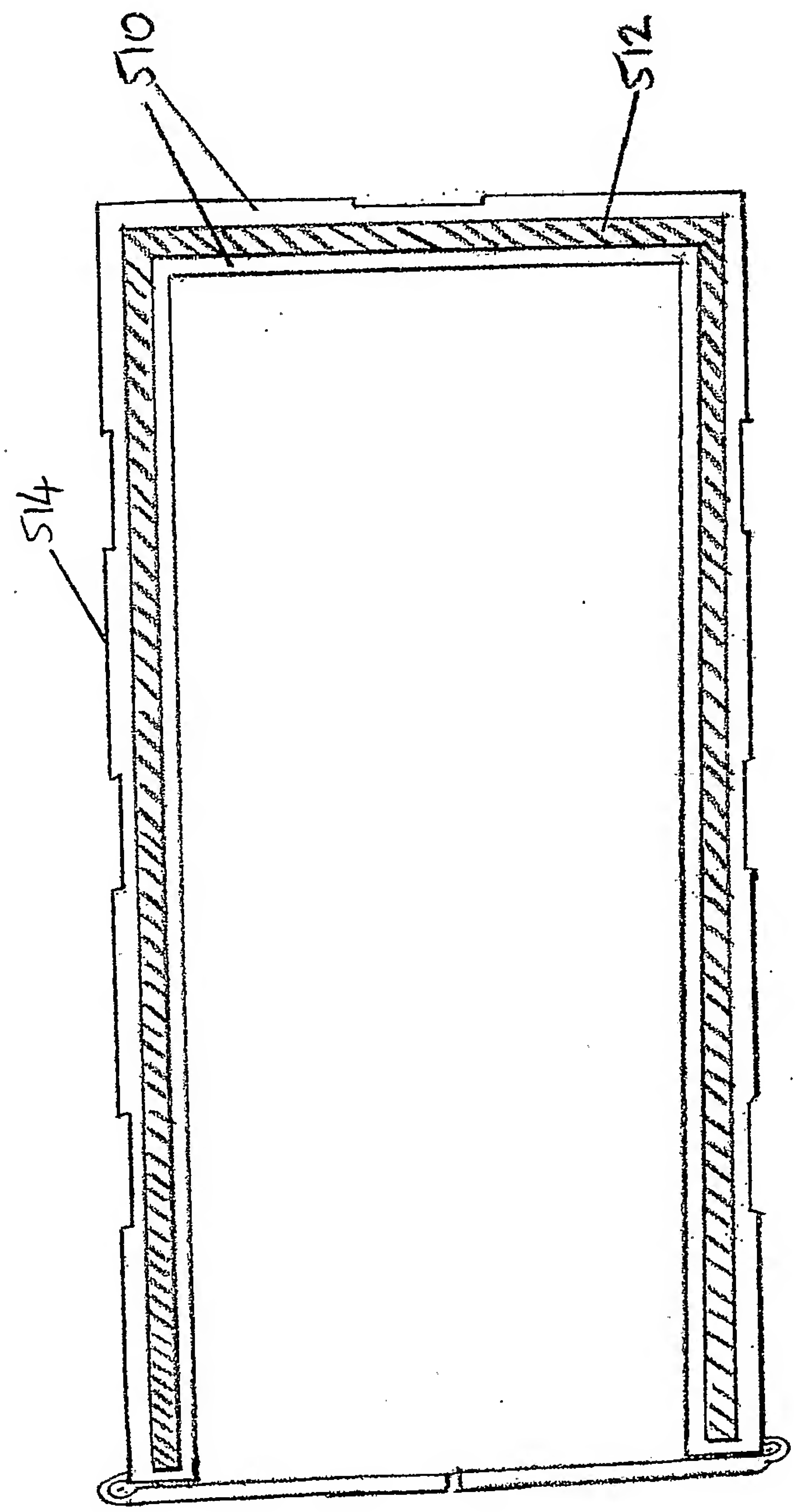


FIG 5

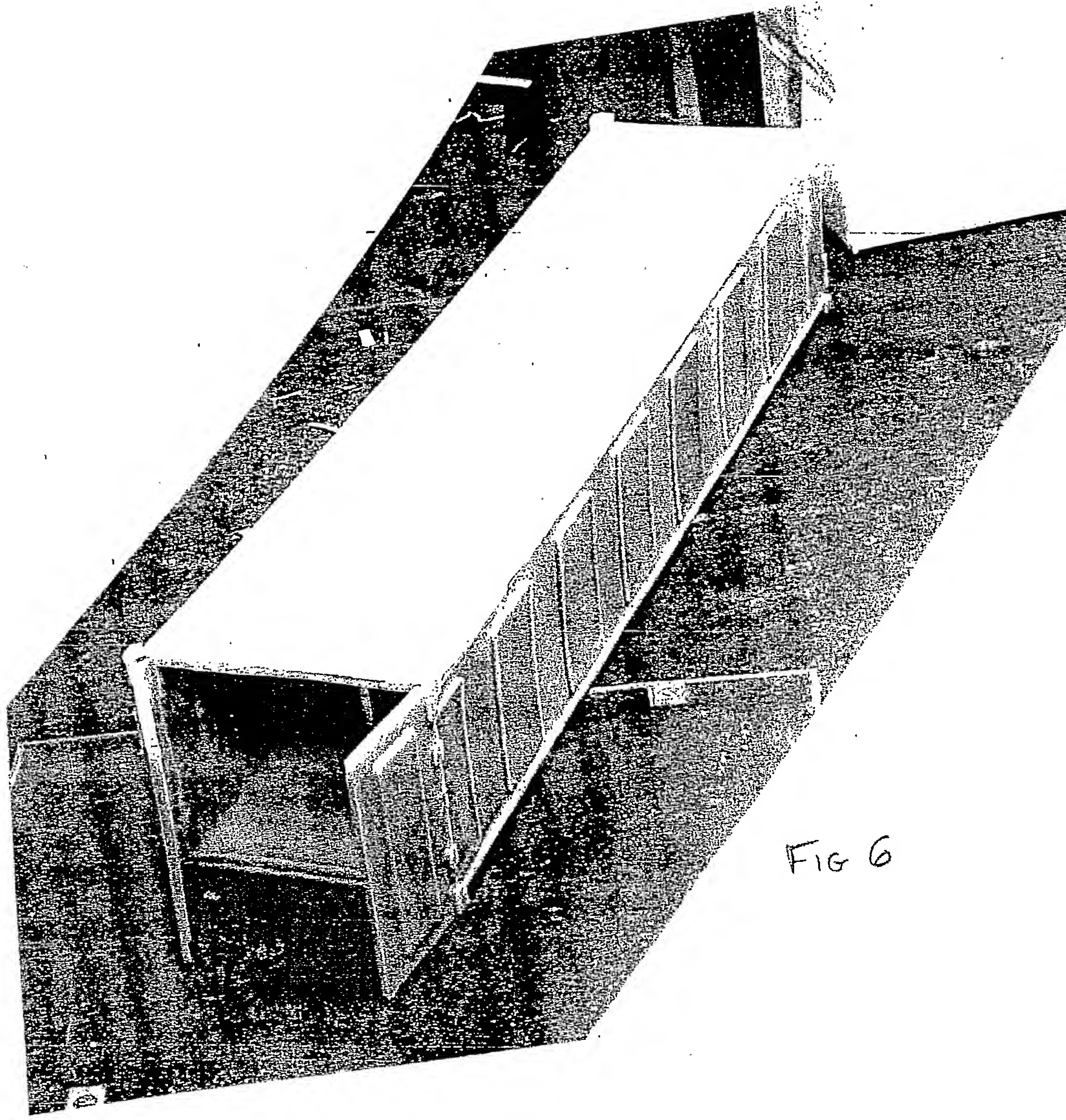


FIG 6

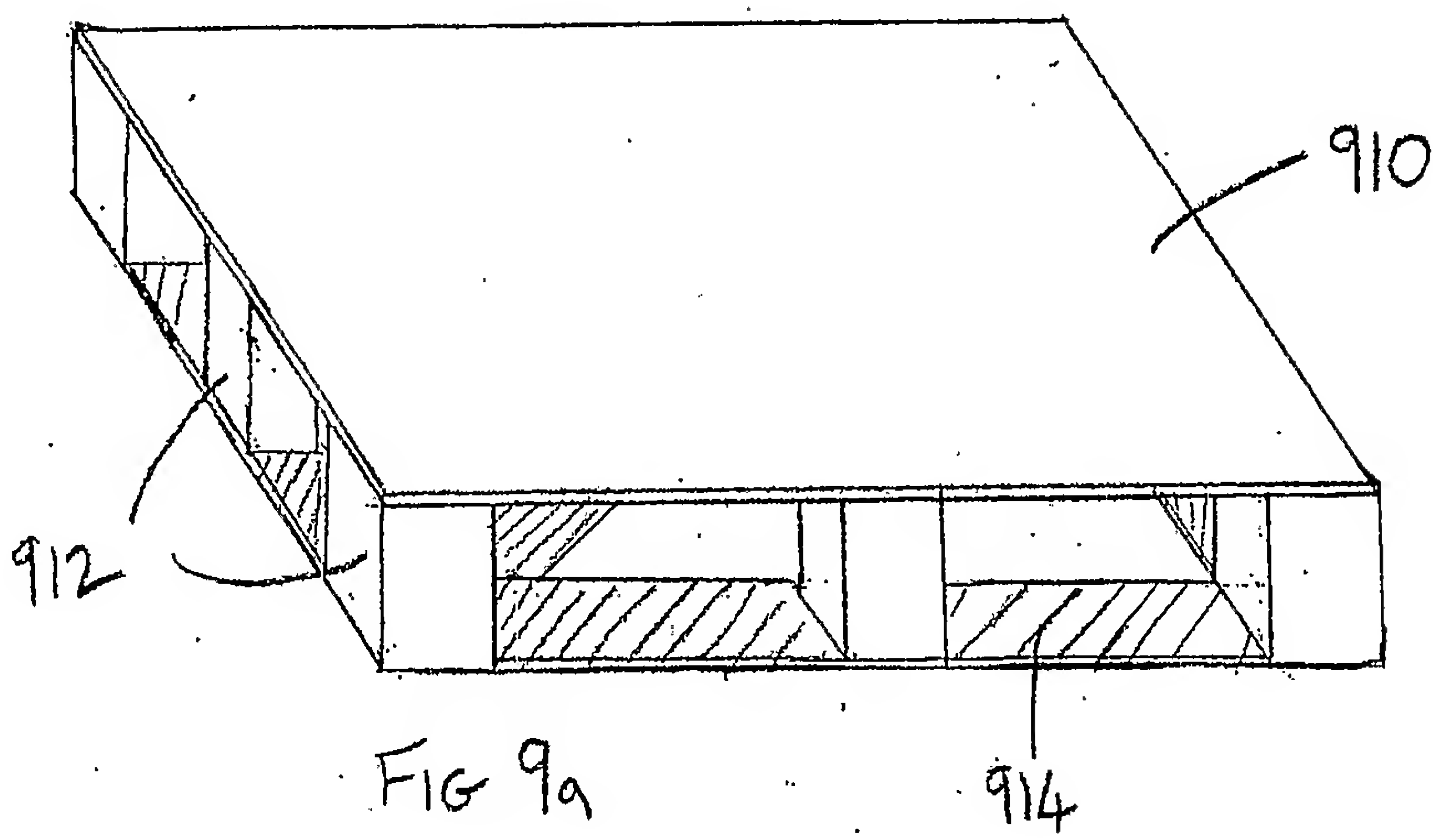


Fig 9a

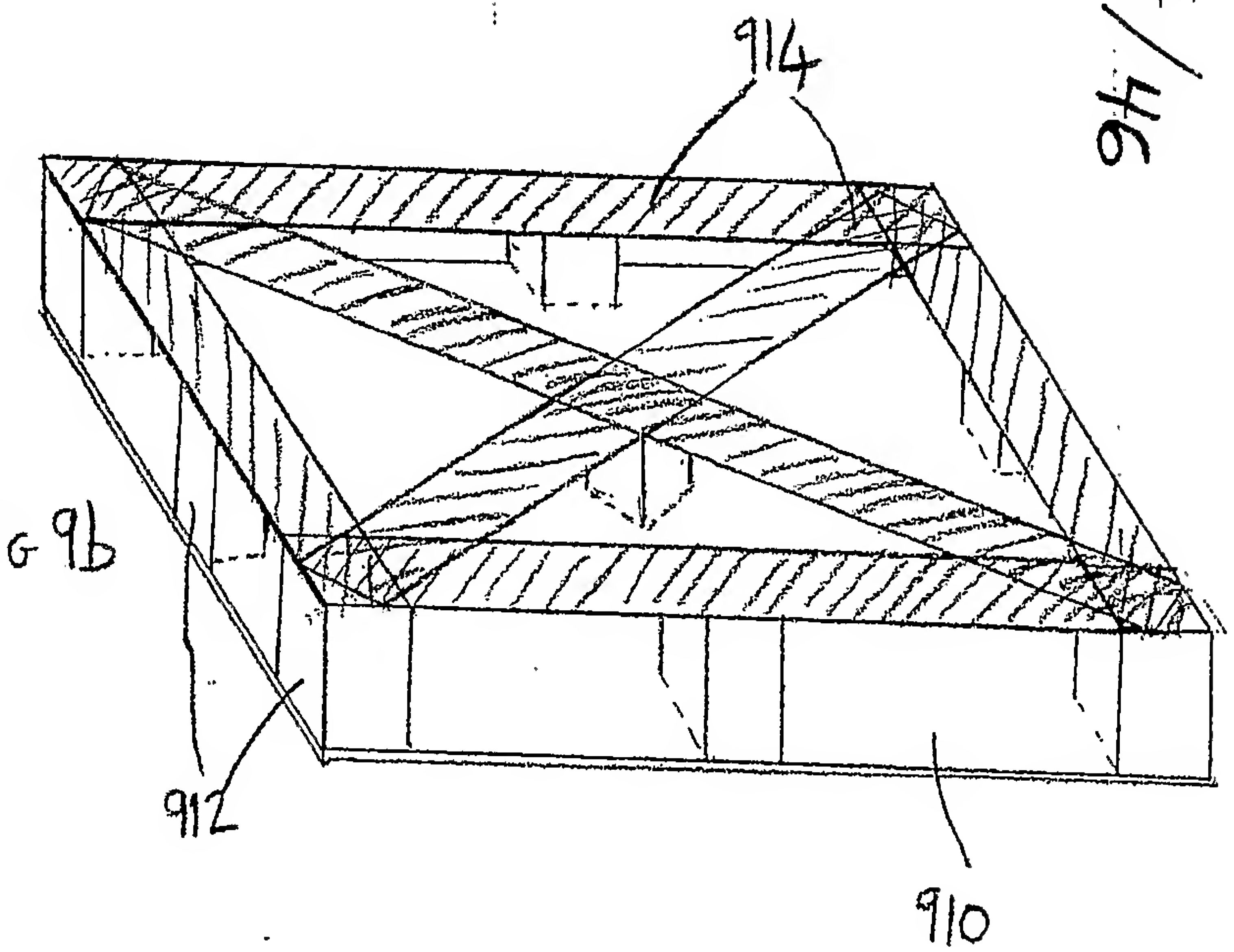


Fig 9b

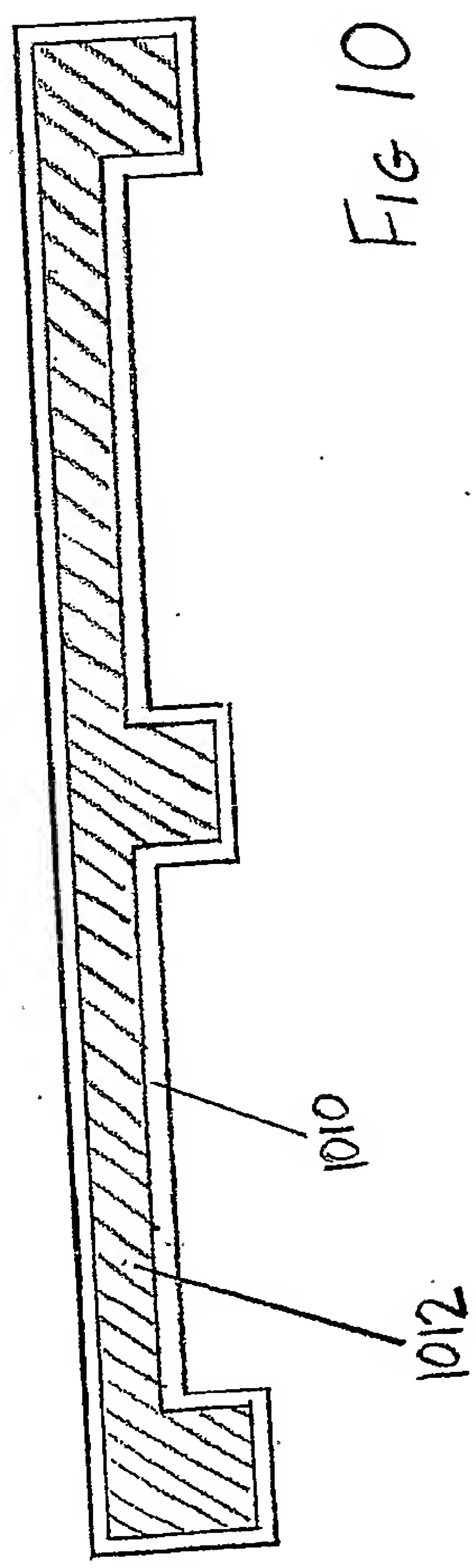


FIG 10

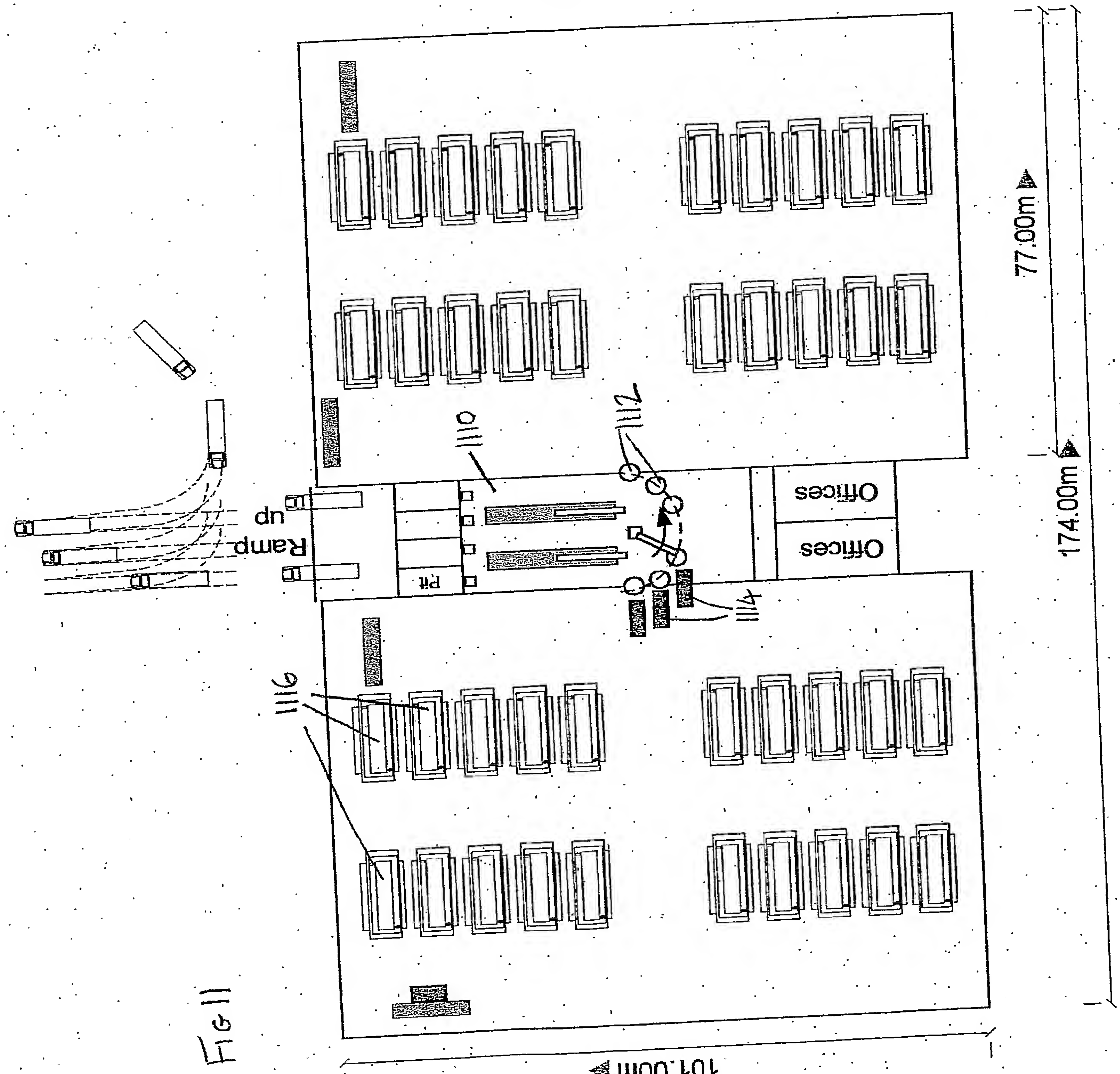

77.00m
174.00m
101.00m
Offices
Offices
Ramp
up
Pit
1110
1112
1114
1116

Fig 11

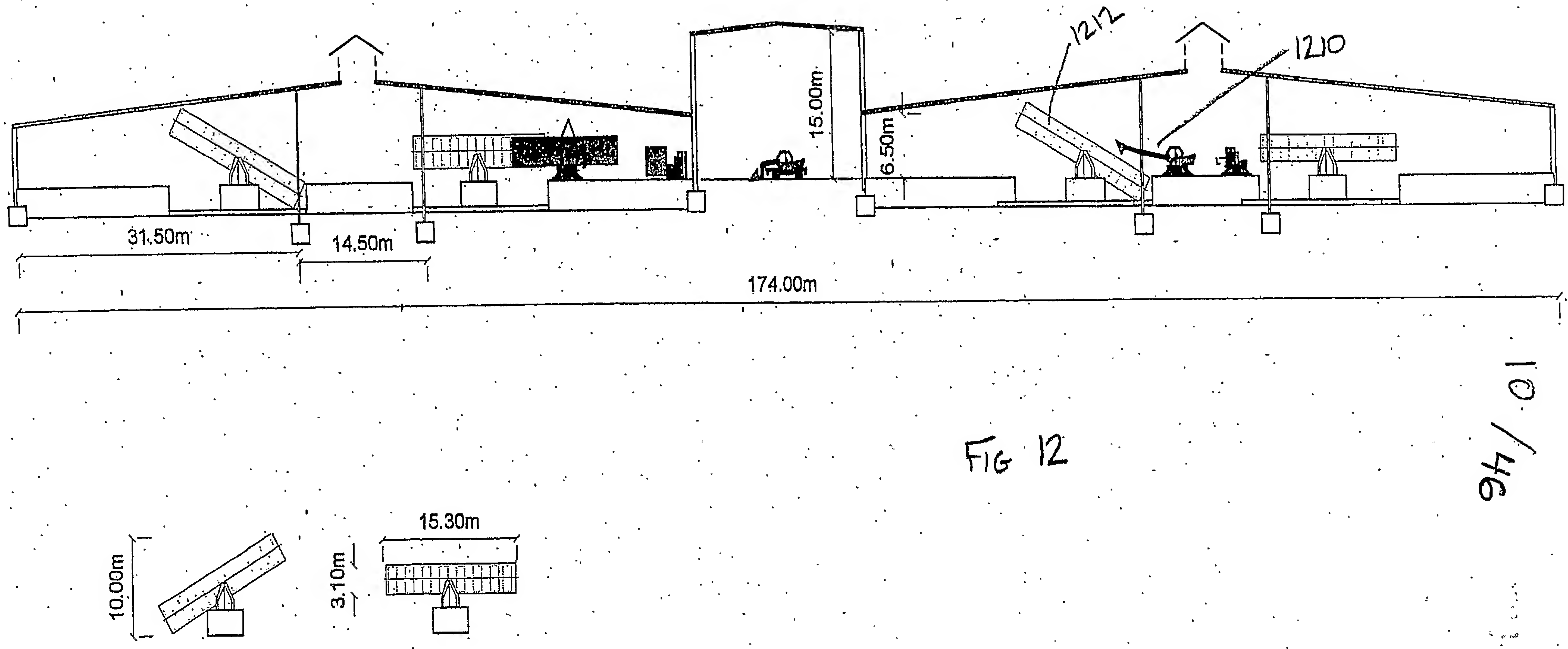


FIG 12

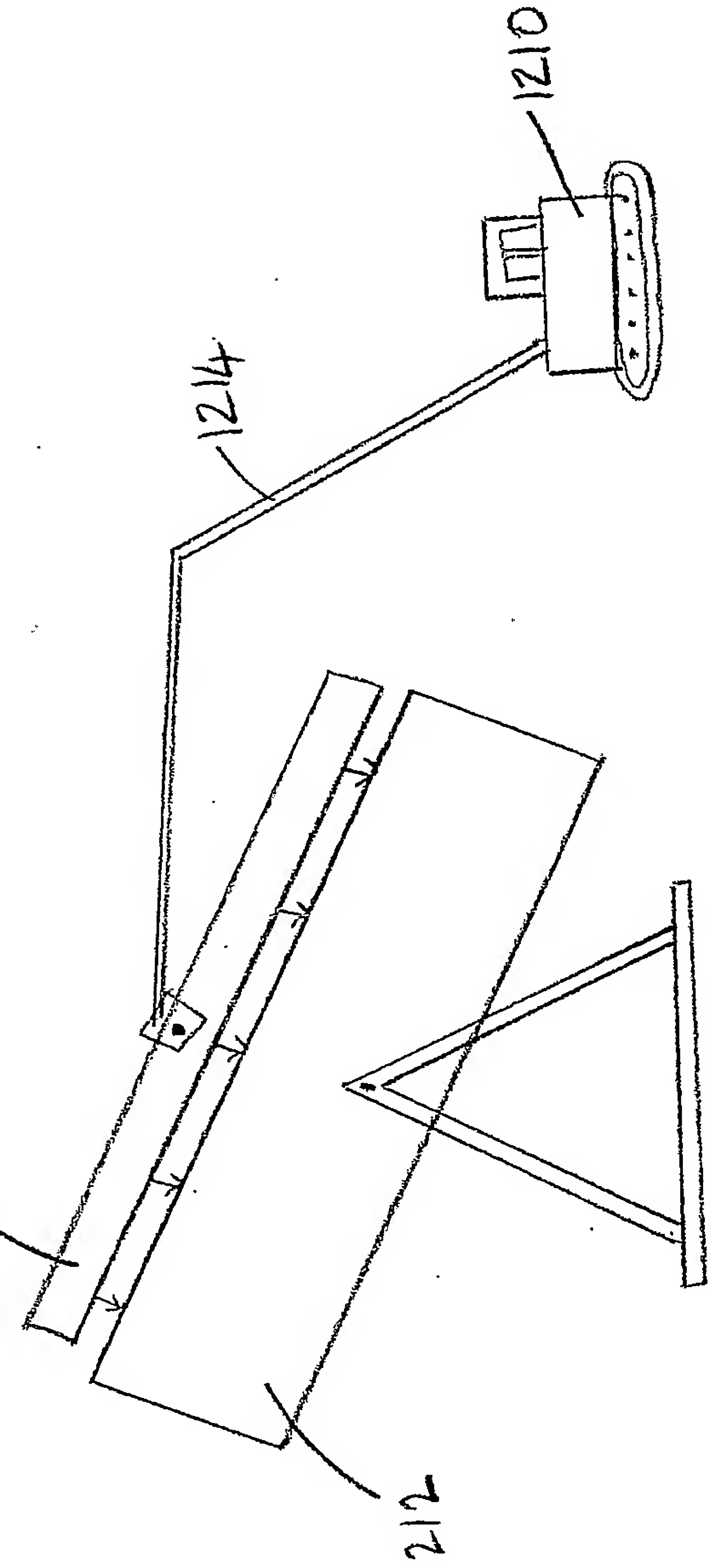
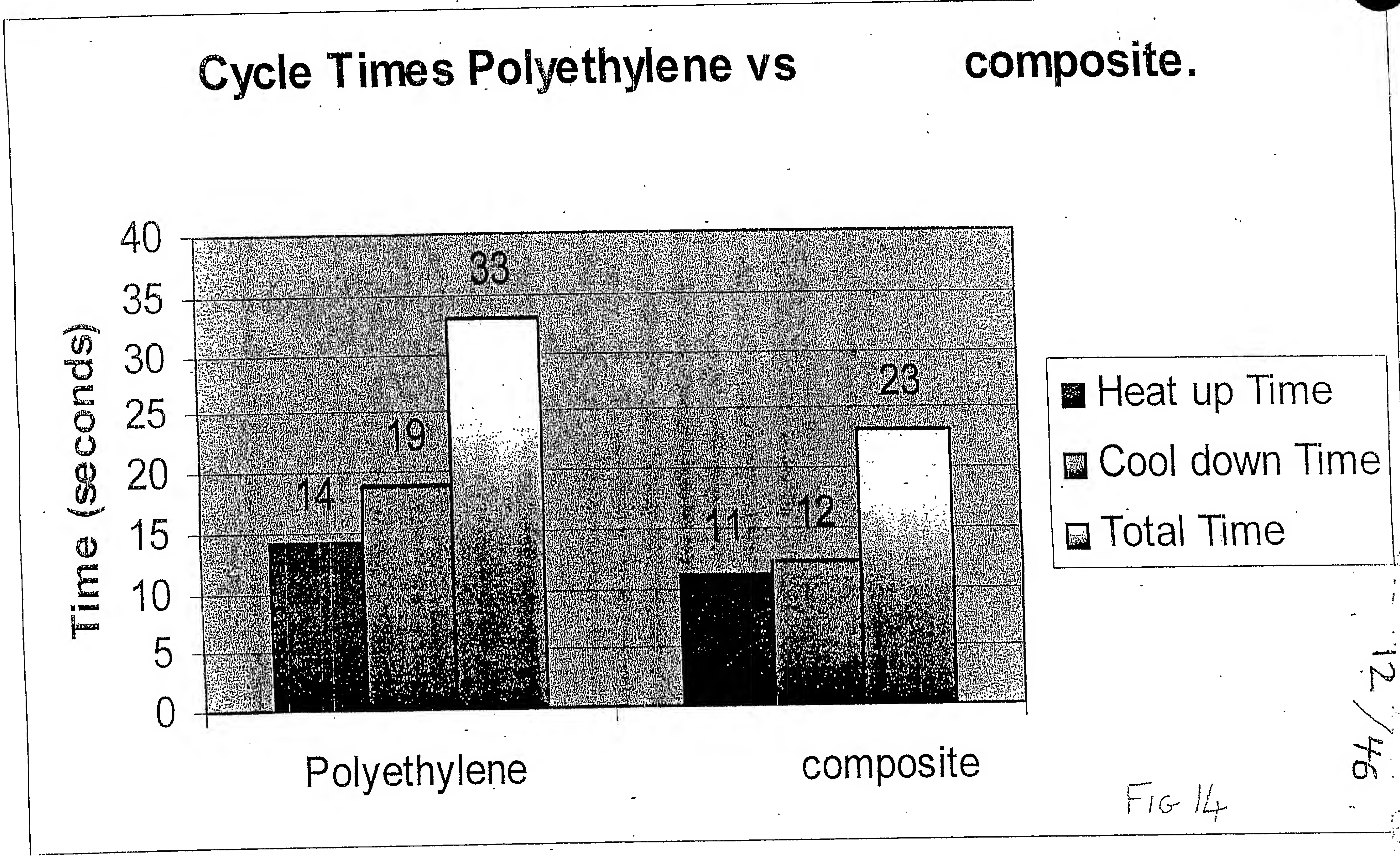
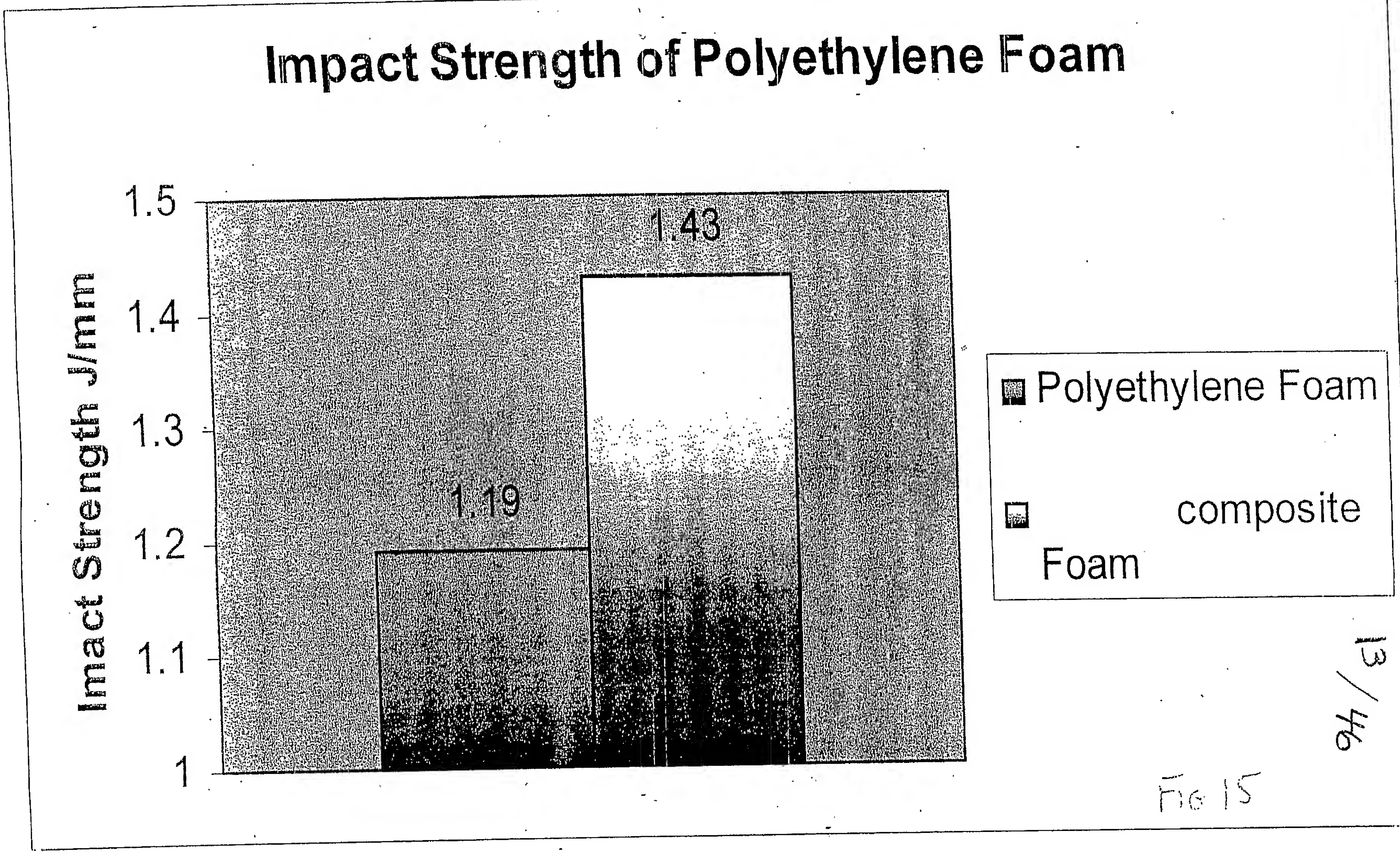


FIG 13



Cycle Times Polyethylene vs composite.
Time (seconds)
40
35
30
25
20
15
10
5
0
14
19
33
11
12
23
Polyethylene
composite
Heat up Time
Cool down Time
Total Time

FIG 14


Impact Strength of Polyethylene Foam
Imact Strength J/mm
1.5
1.4
1.3
1.2
1.1
1
1.19
1.43
Polyethylene Foam
composite Foam

13/46

Fig 15

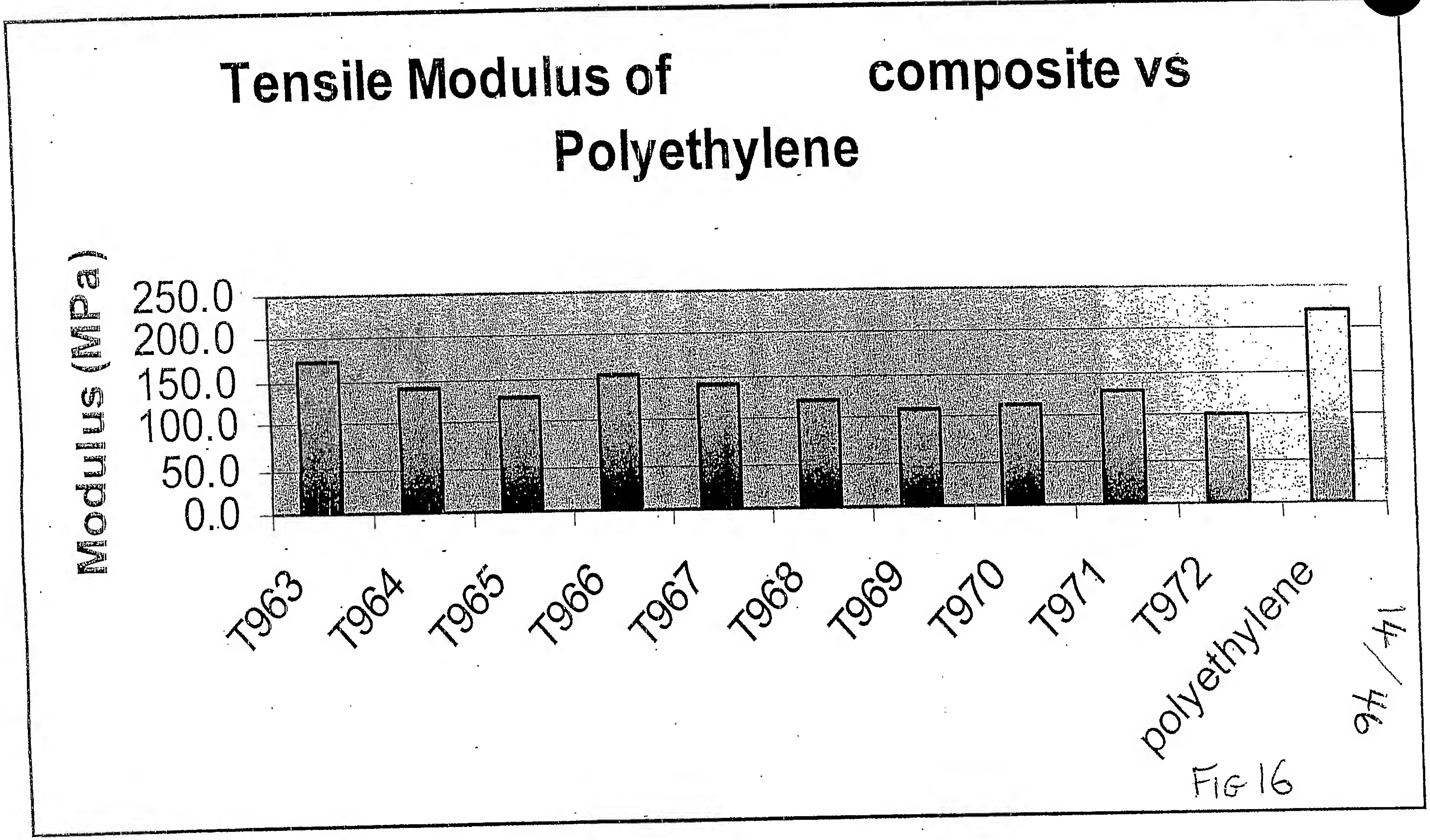

Tensile Modulus of composite vs Polyethylene
Modulus (MPa)
250.0
200.0
150.0
100.0
50.0
0.0
T963
T964
T965
T966
T967
T968
T969
T970
T971
T972
polyethylene

FIG 16

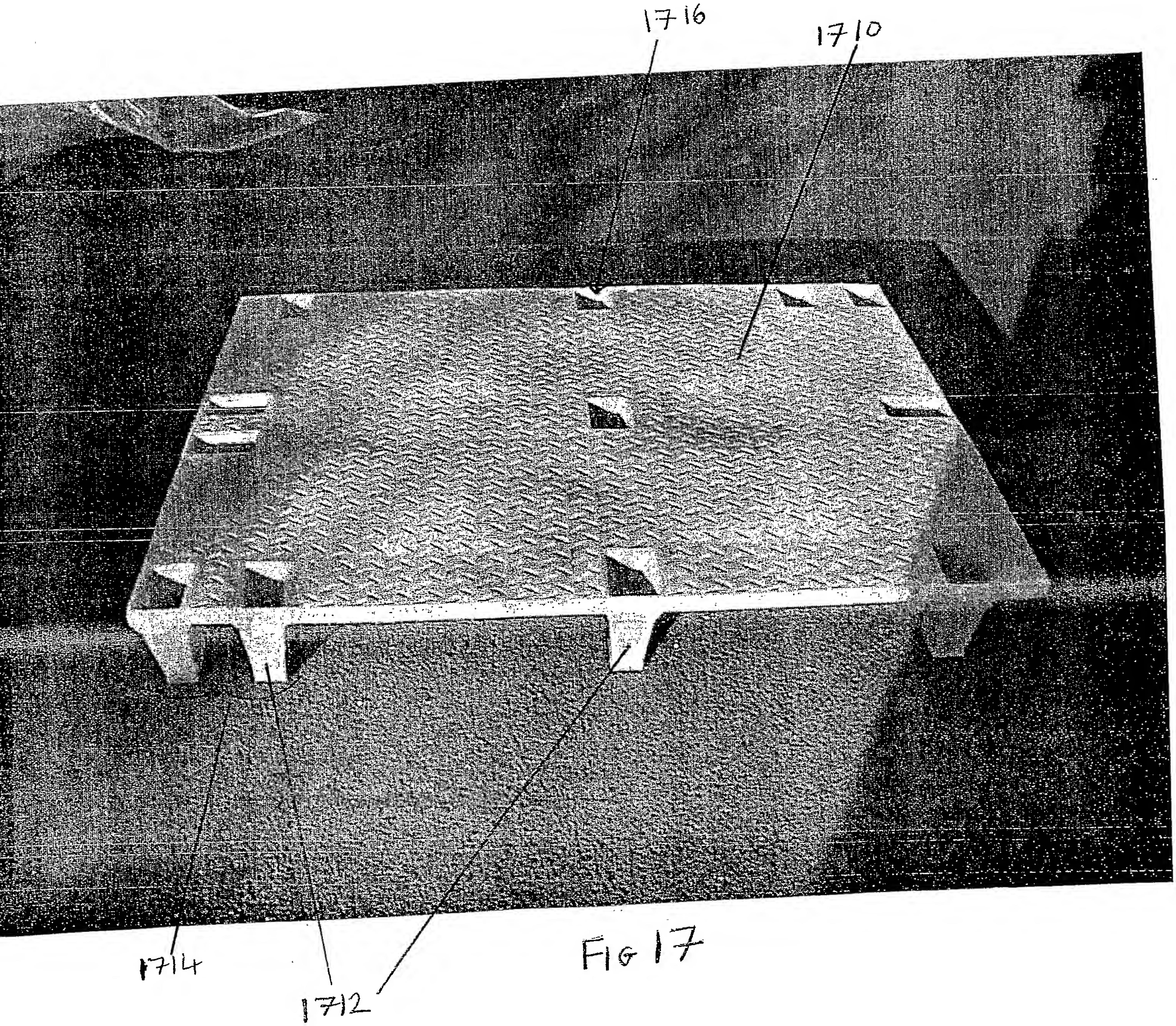


FIG 17

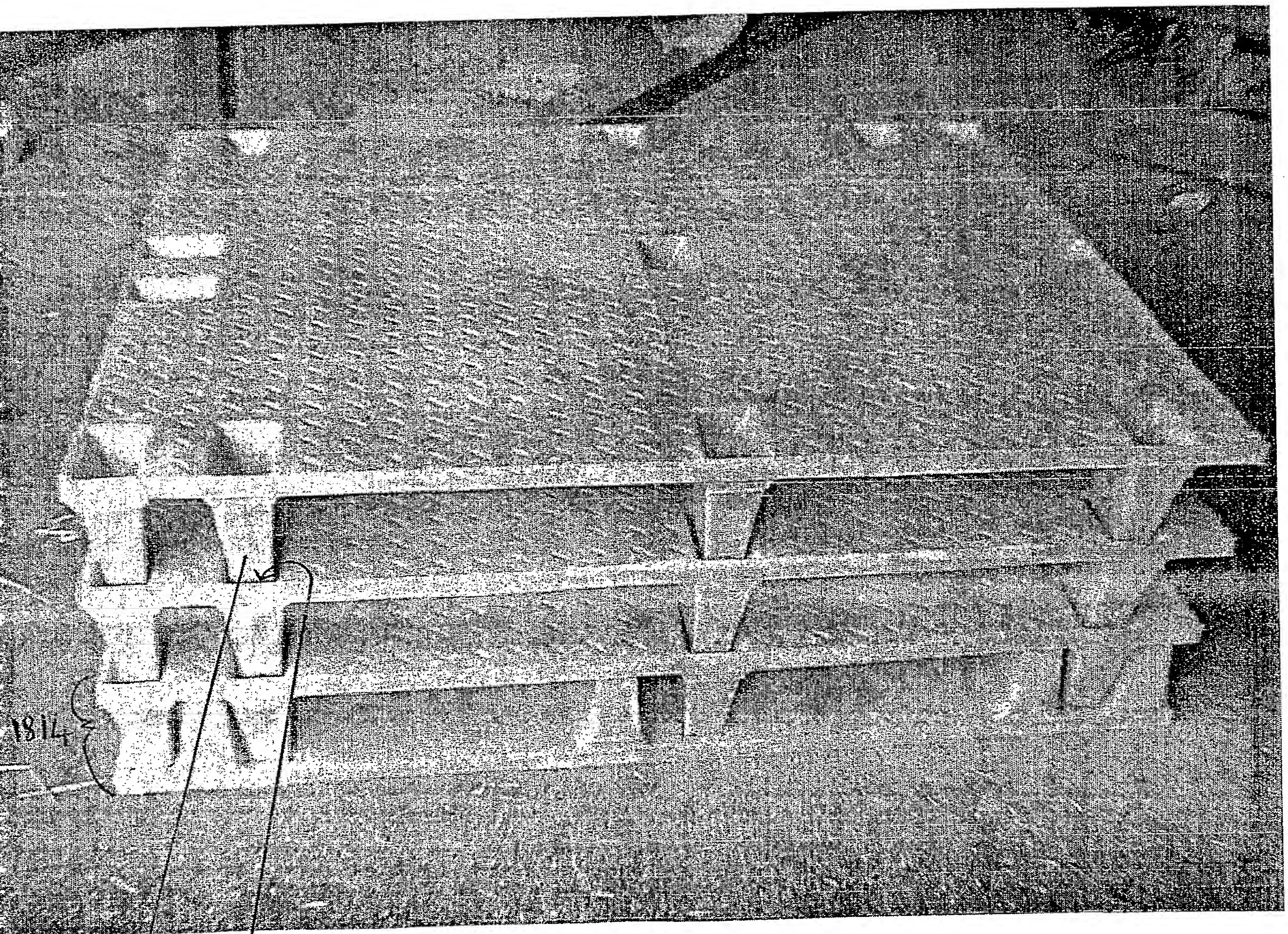


FIG 18

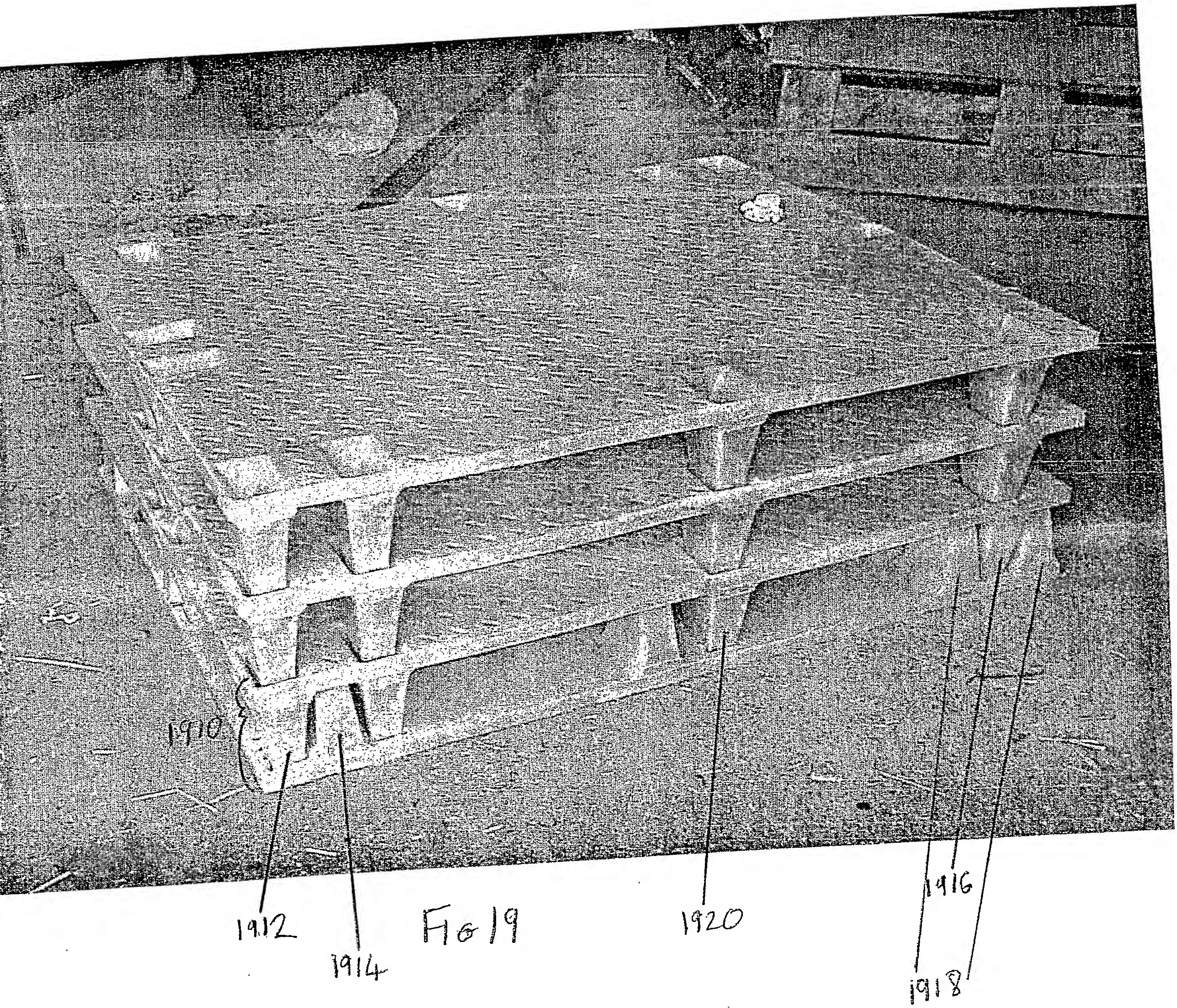


FIG 19

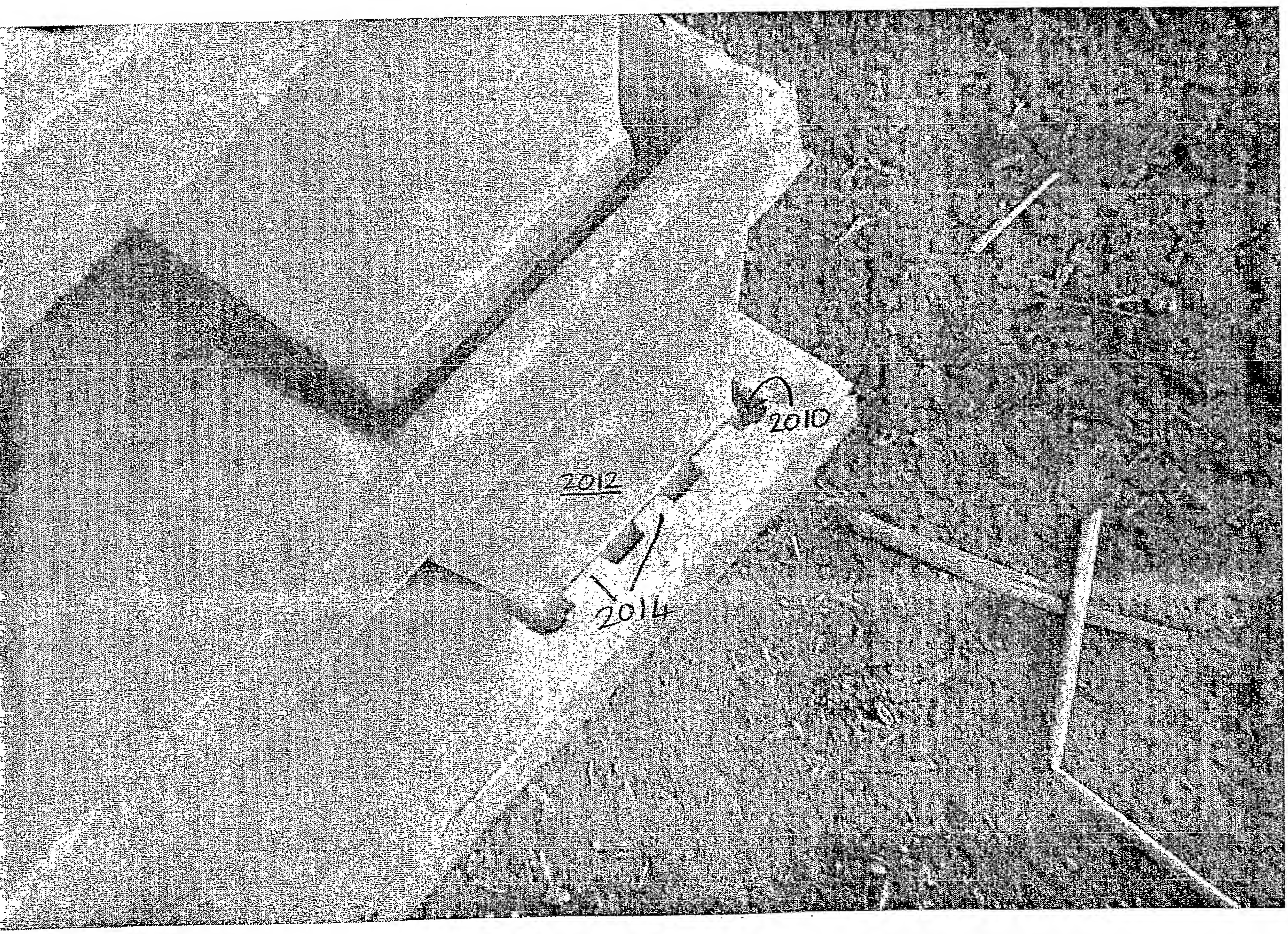


FIG 20

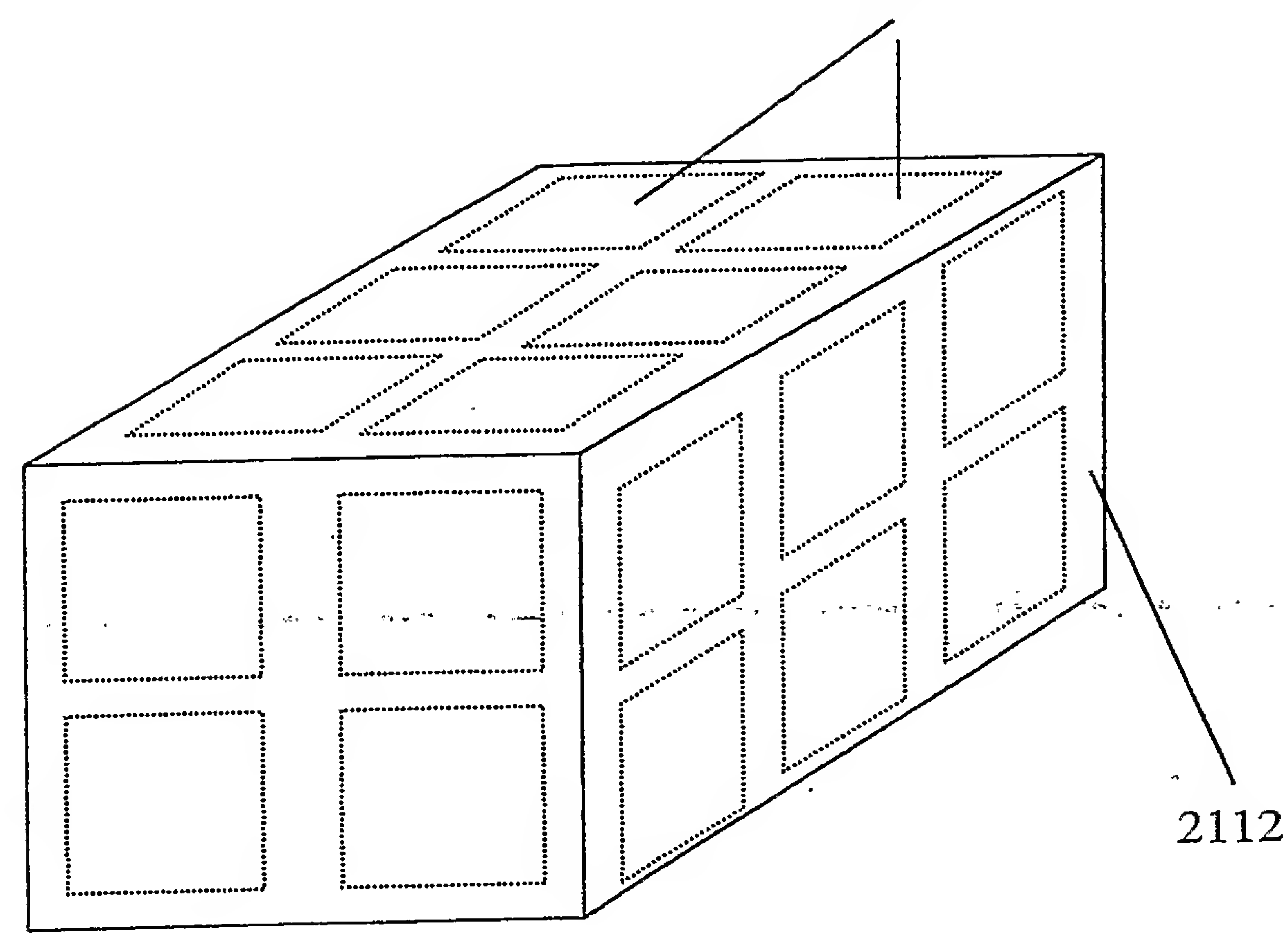


Fig. 21

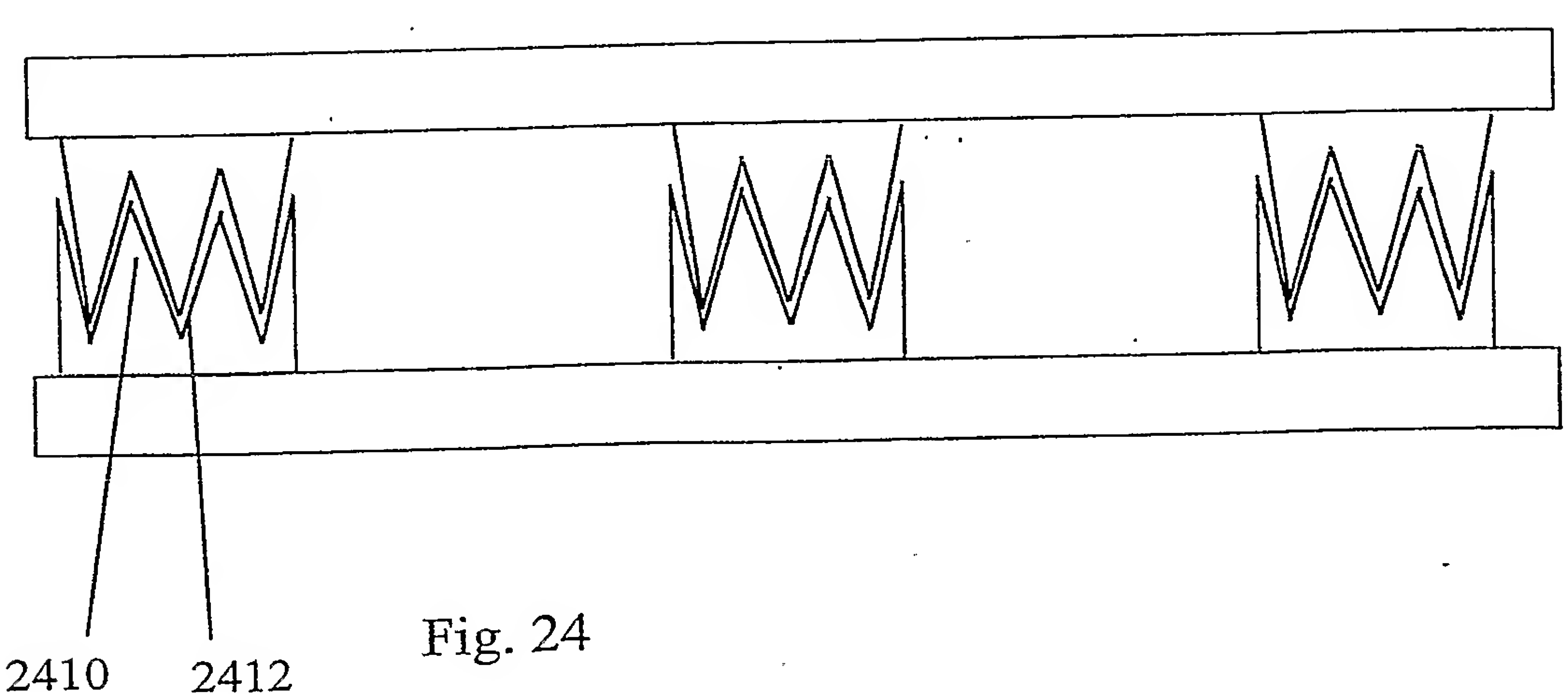


Fig. 24

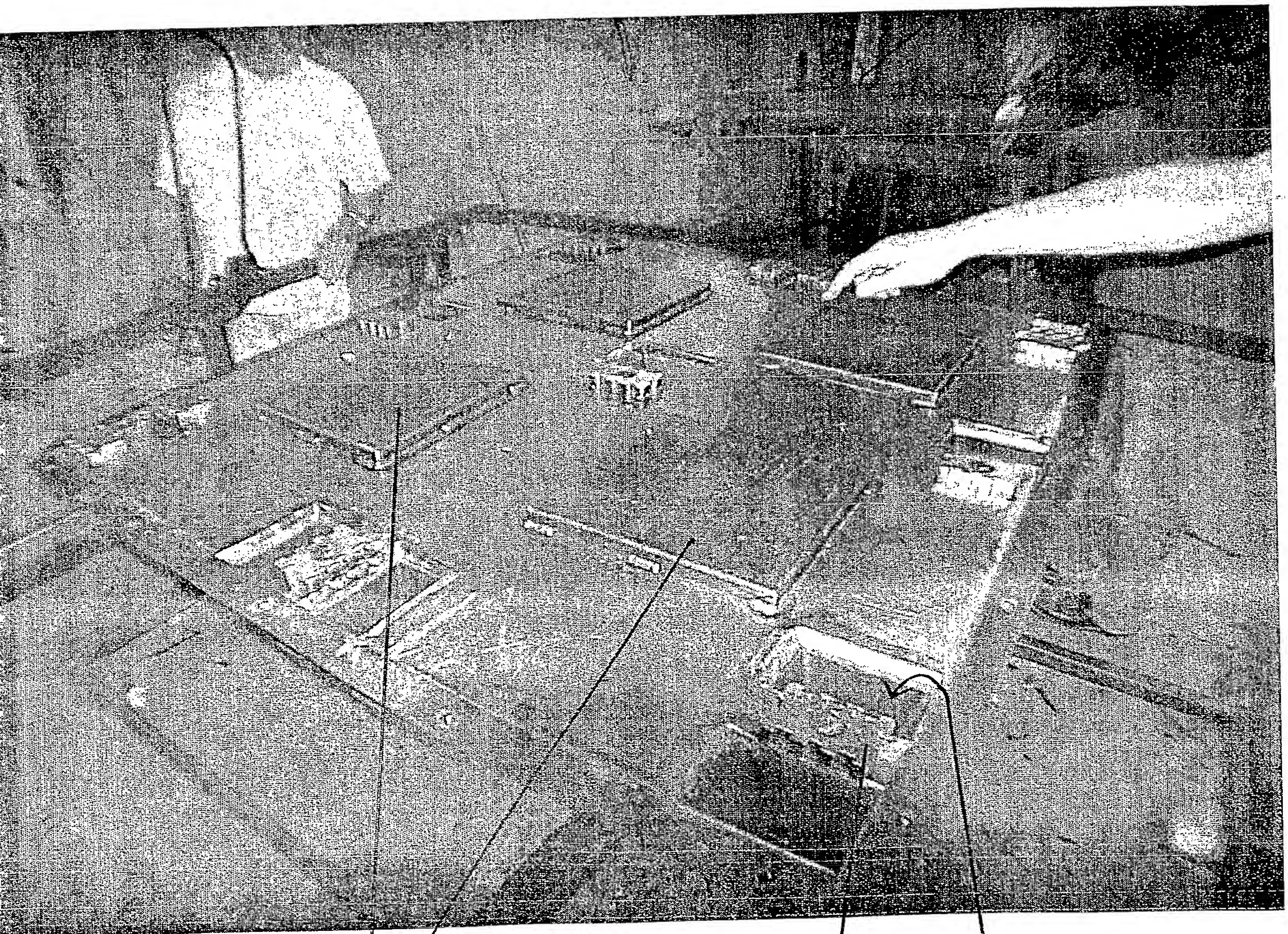
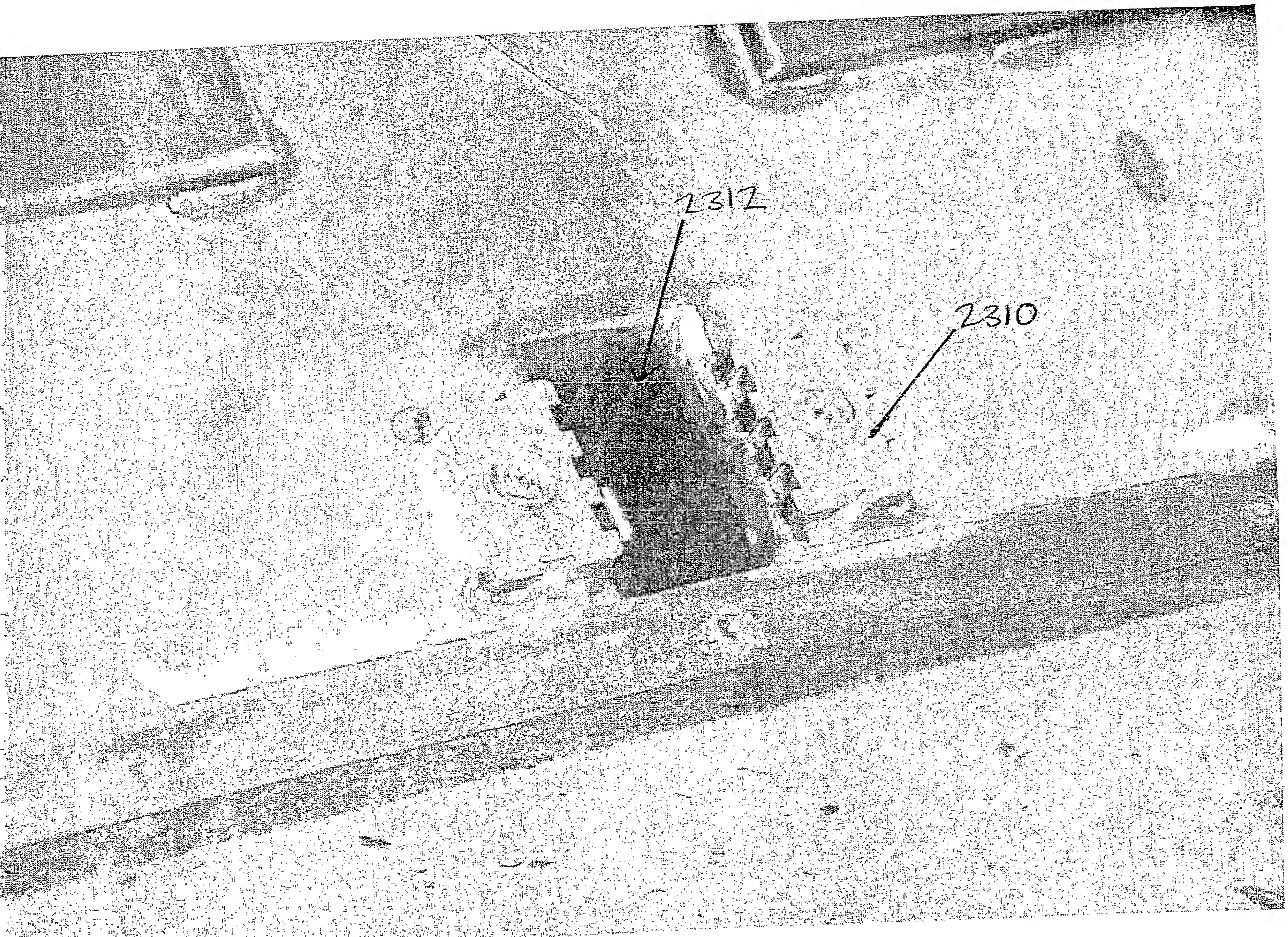


FIG 22


2312
2310

22/46

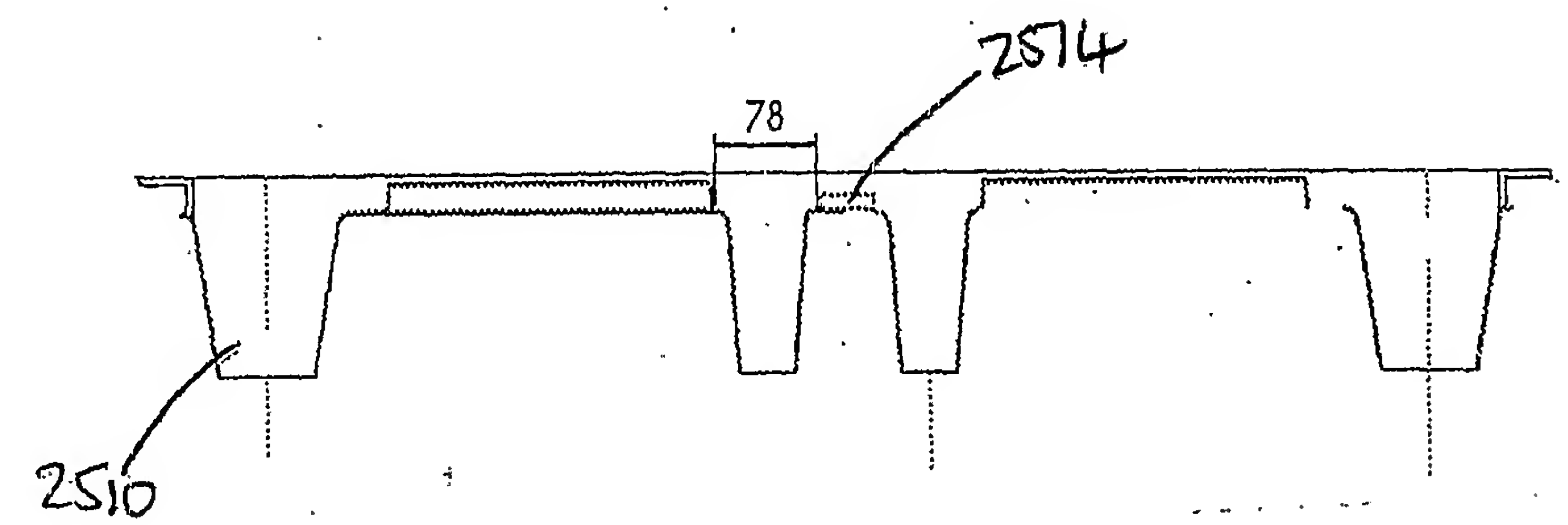


FIG 26

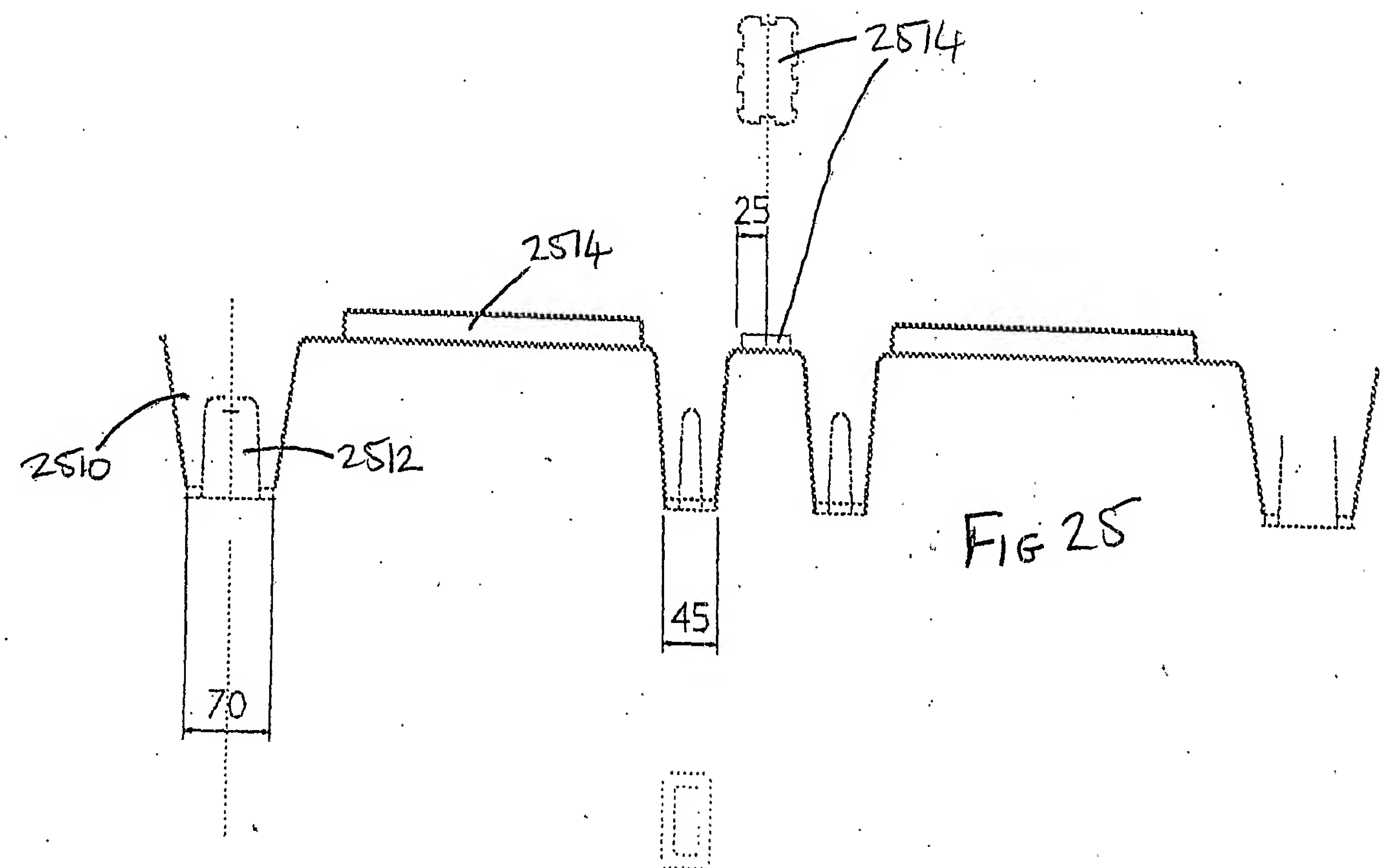


FIG 25

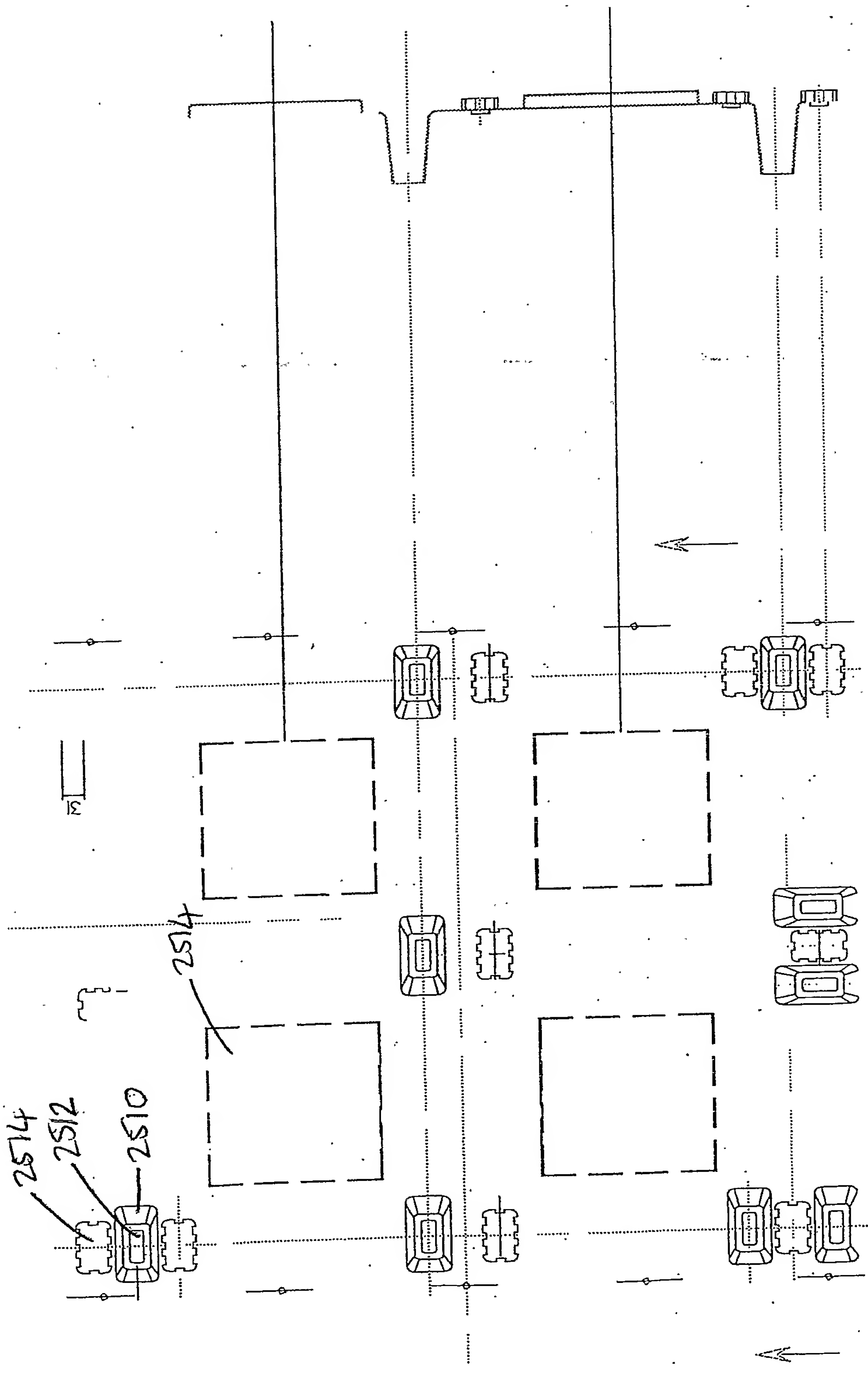


FIG 27

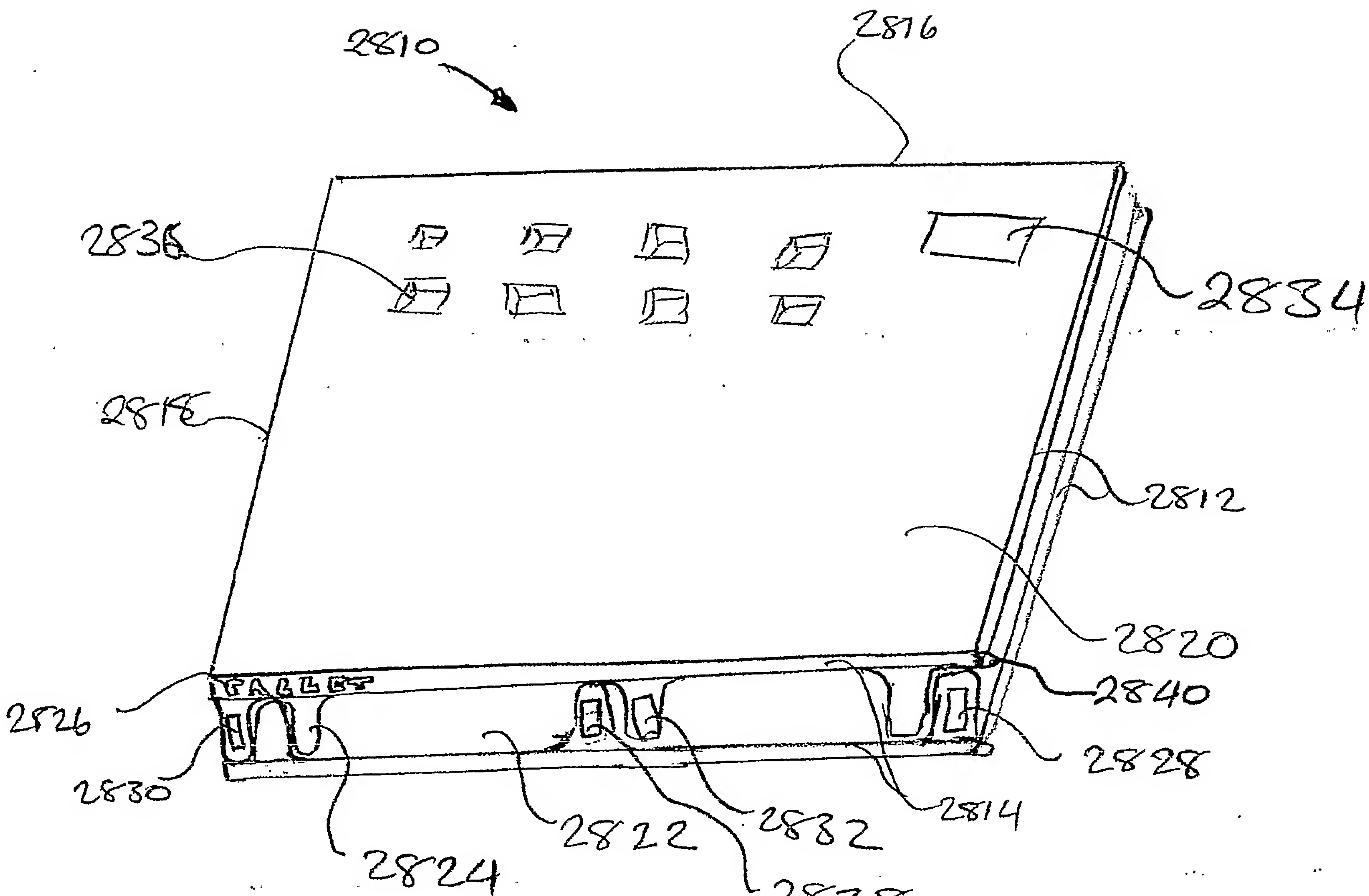
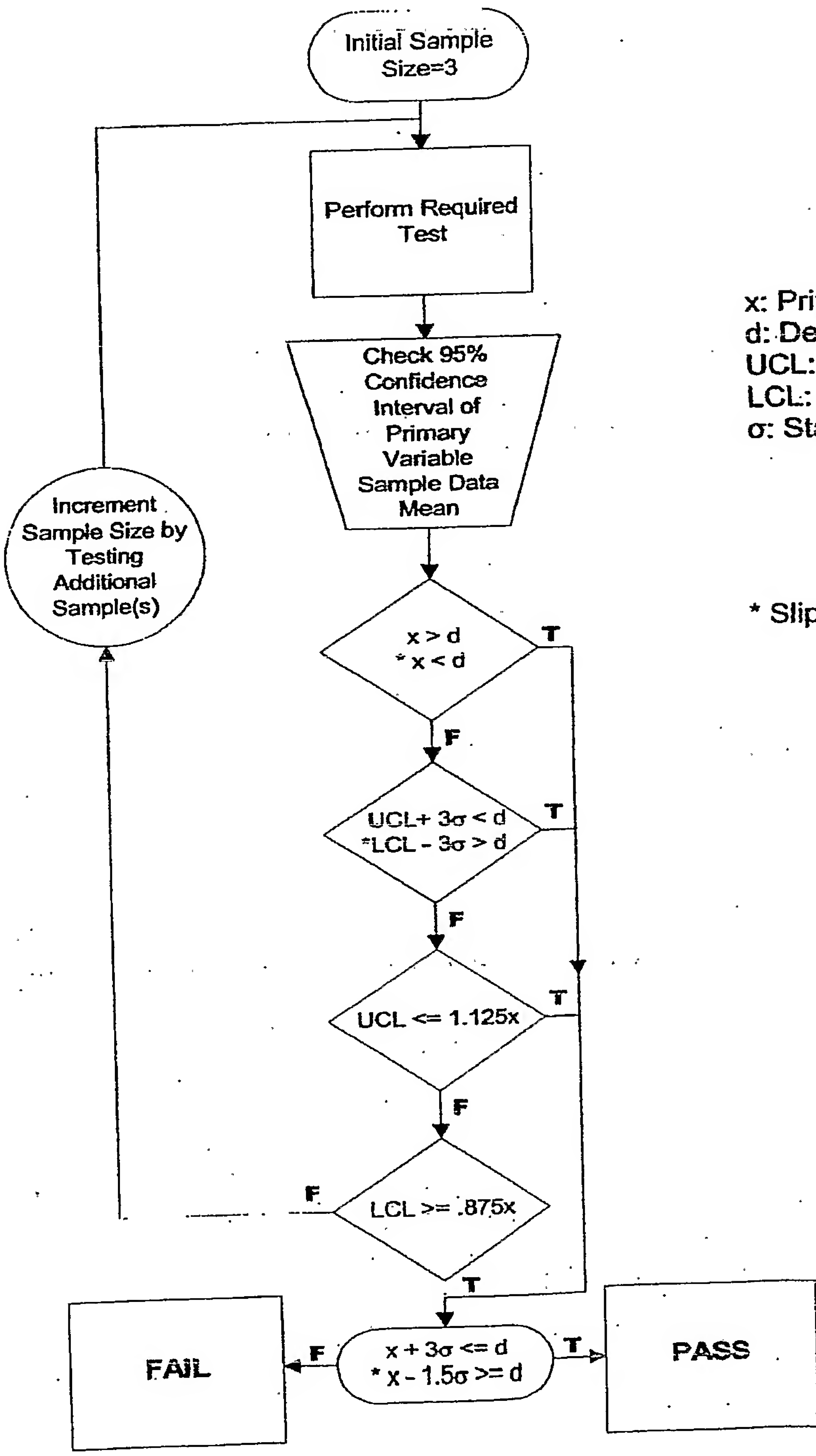

2810
2816
2836
2834
2818
2812
2820
2840
2826
2828
2830
2824
2822
2832
2814
2838
PALLET

Fig 28



Legend:

x: Primary Data Sample Mean
d: Deflection Limit
UCL: Upper Confidence Limit
LCL: Lower Confidence Limit
σ: Standard Deviation

* Slip Resistance tests

Fig 29B

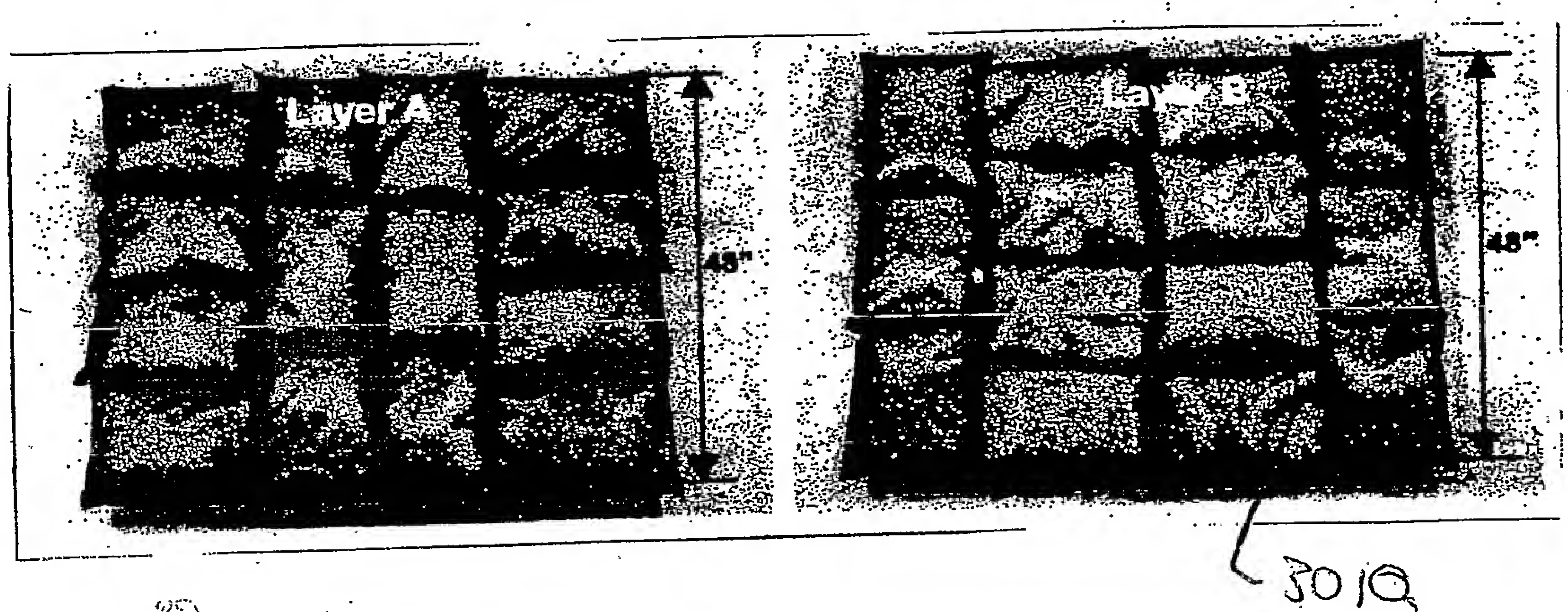


Fig30a and30b

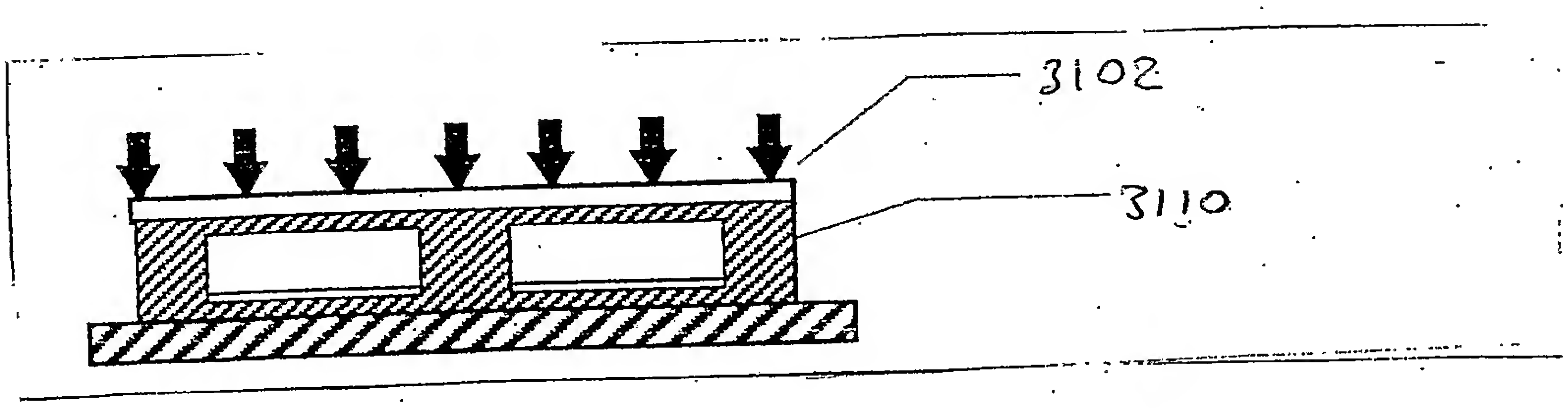


Fig.31

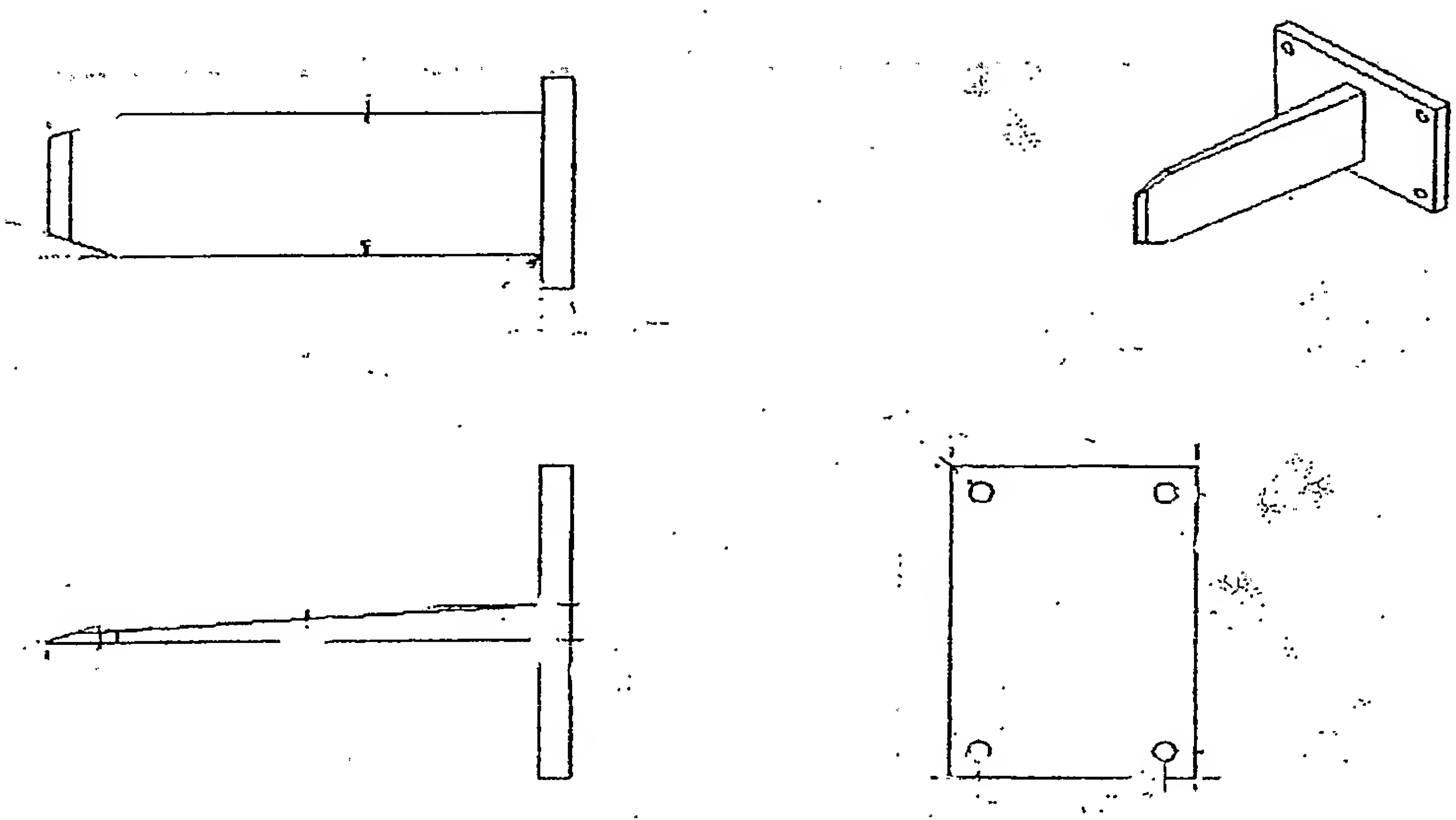


Fig 32

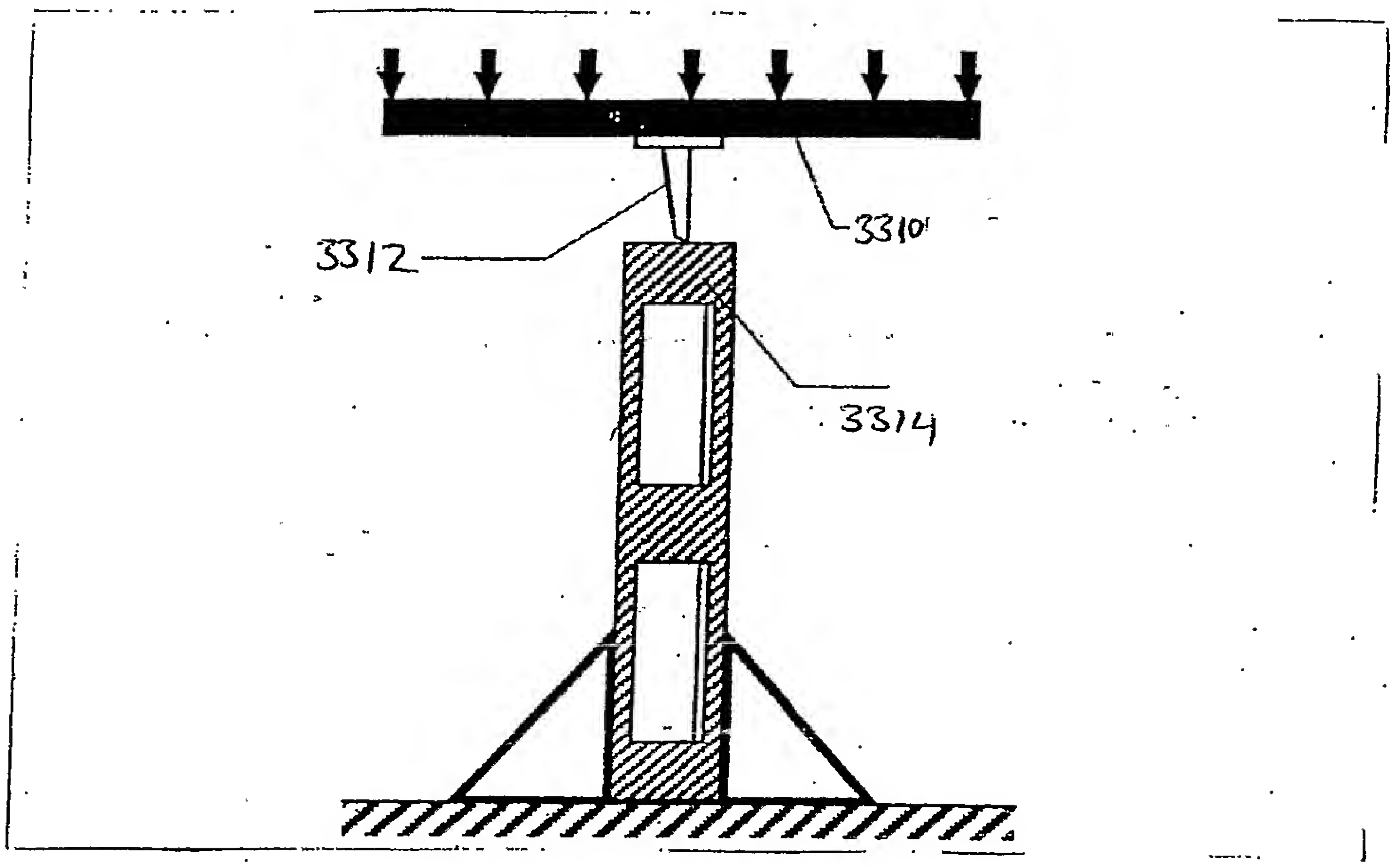


Fig.33

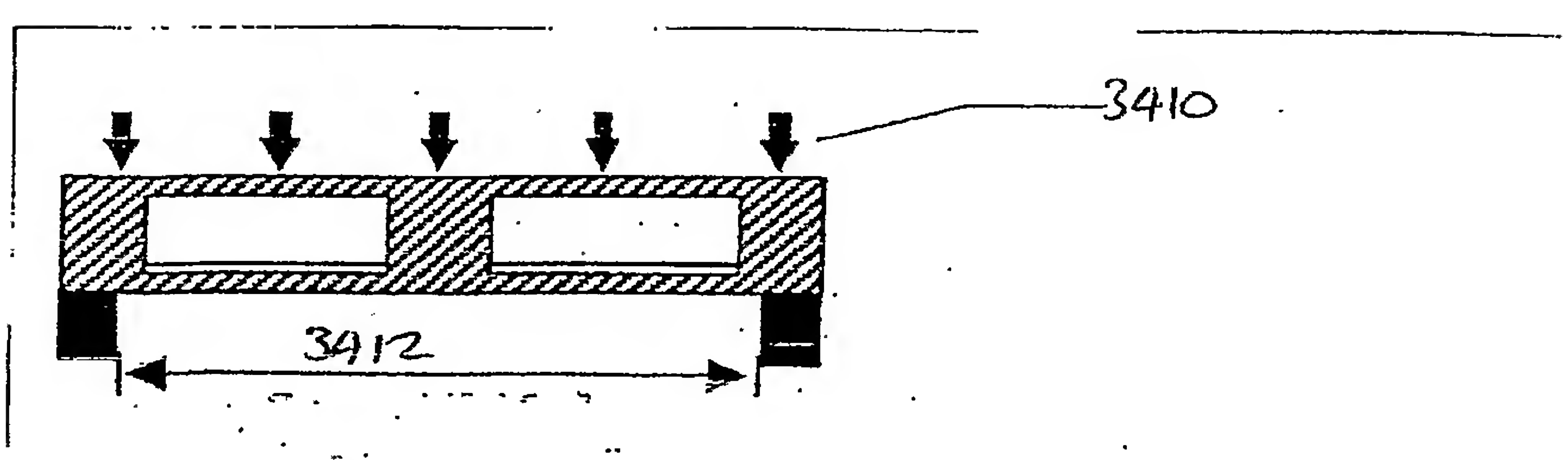


Fig.34

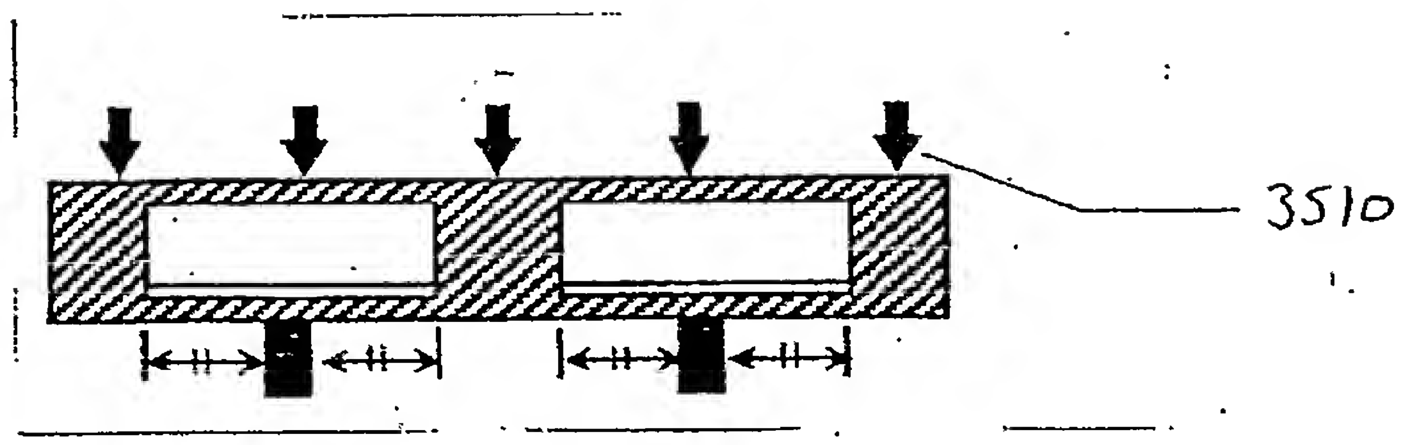


Fig.35

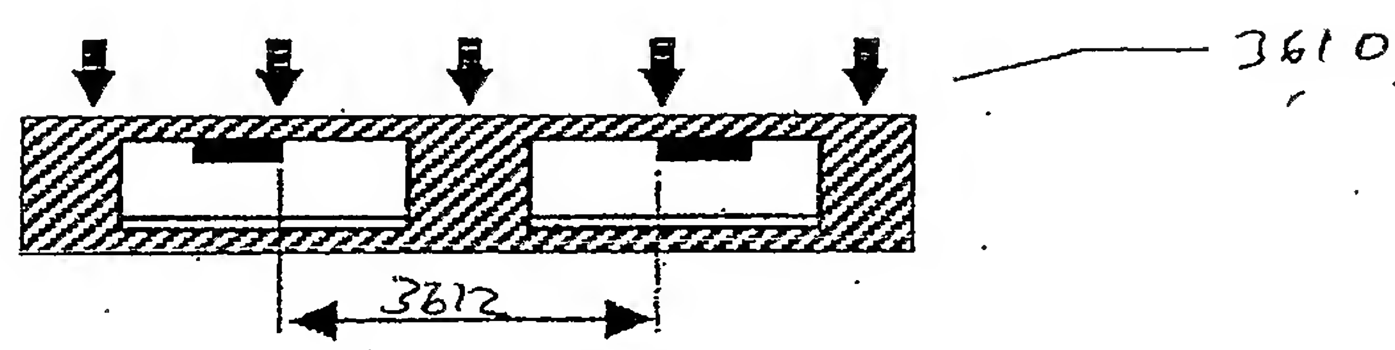


Fig 36

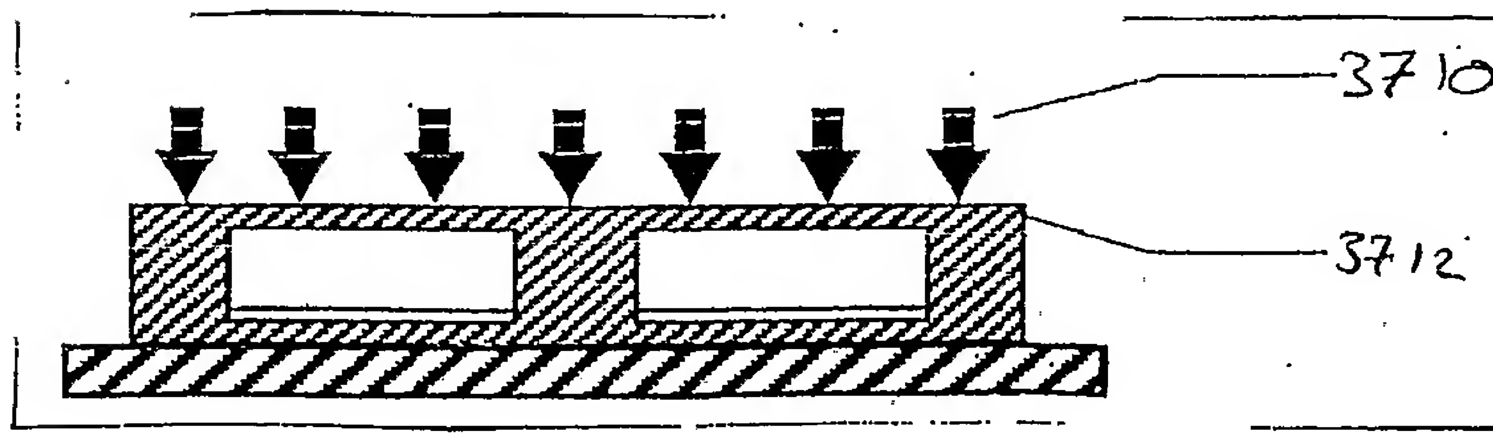


Fig.37

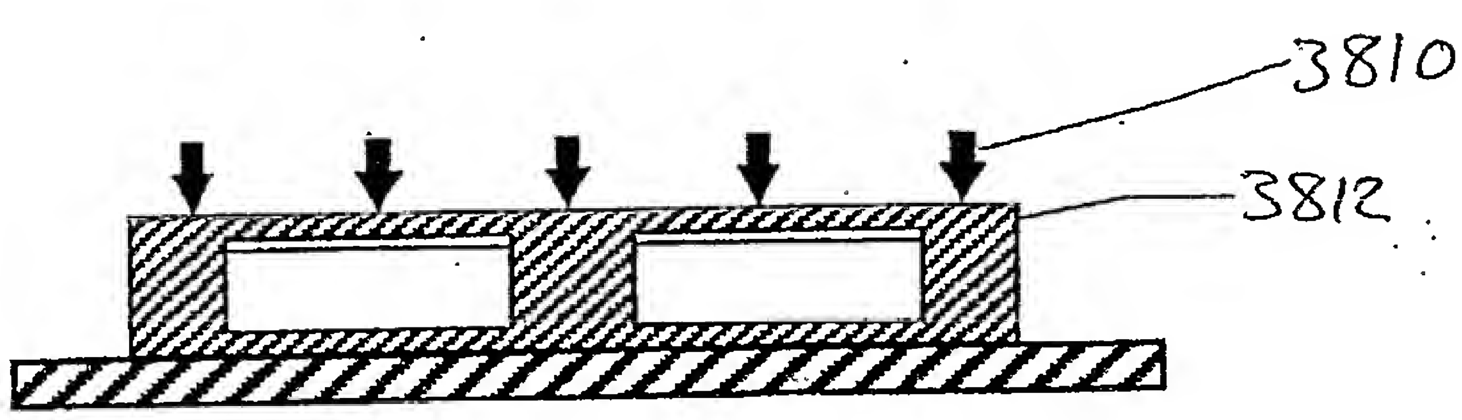


Fig. 38

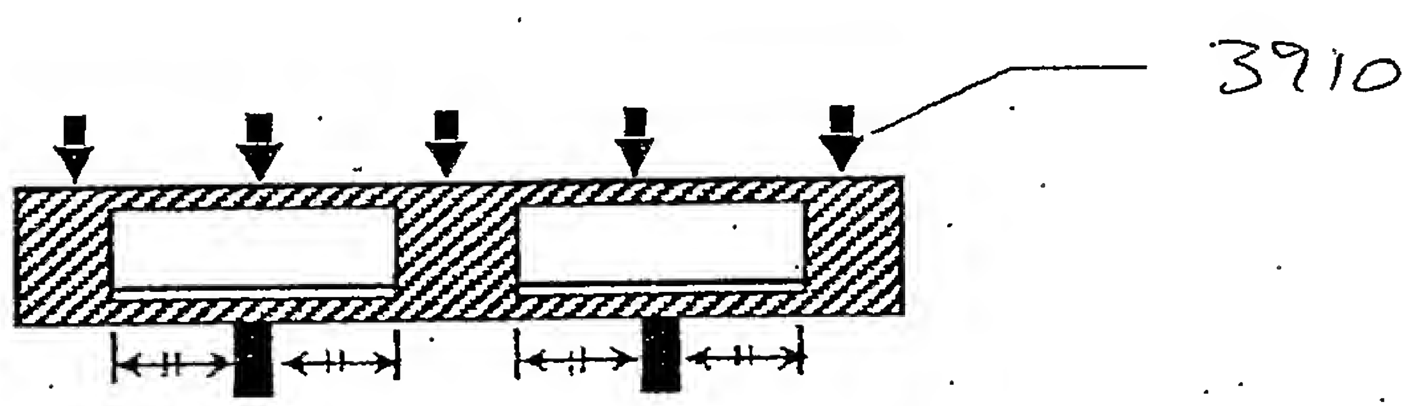


Fig. 39

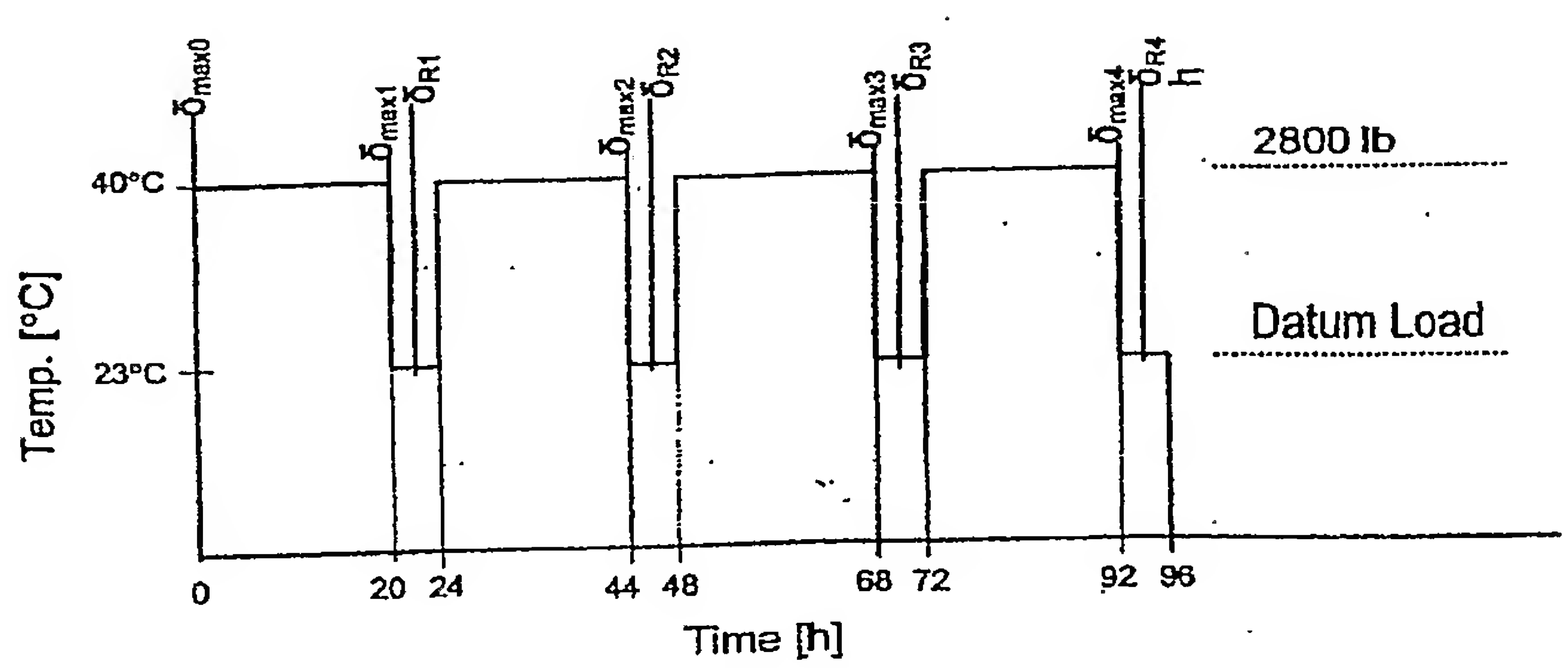


Fig. 40a

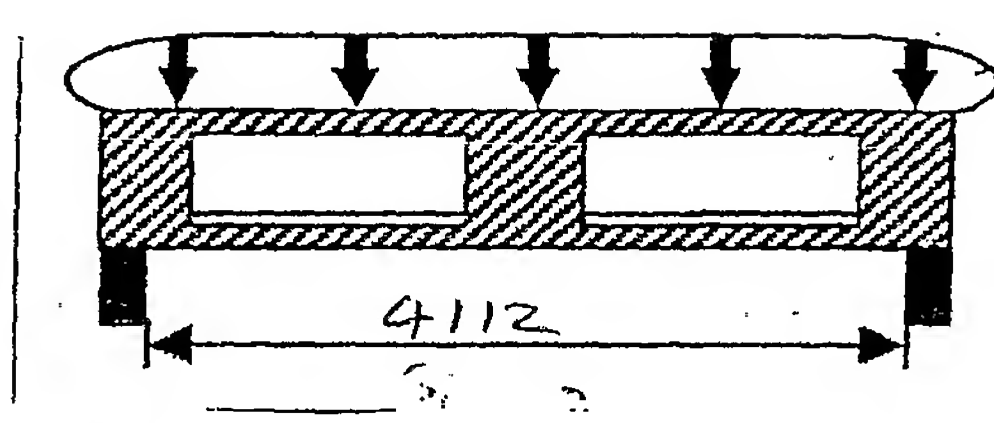


Fig. 41

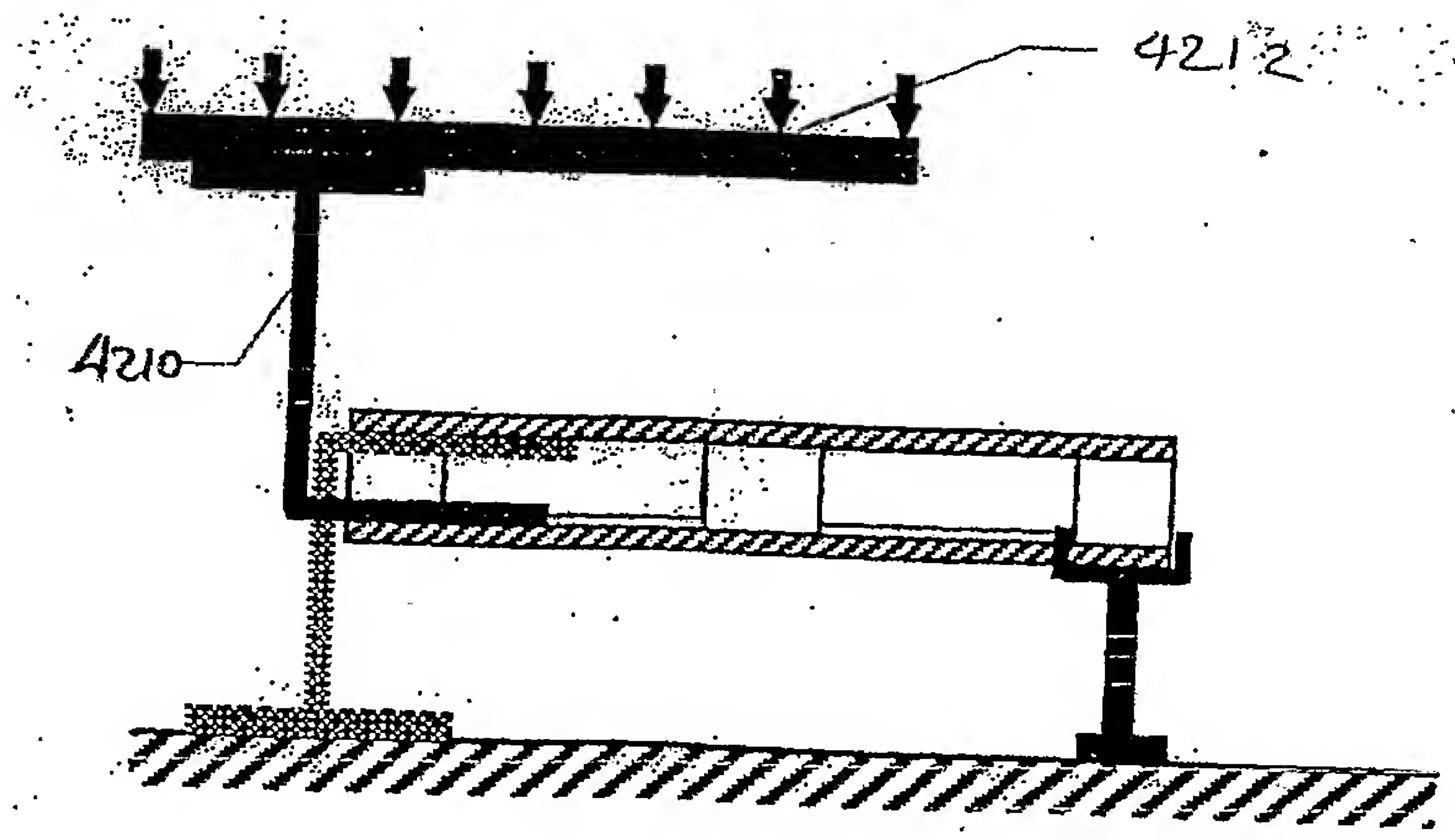


Fig. 42

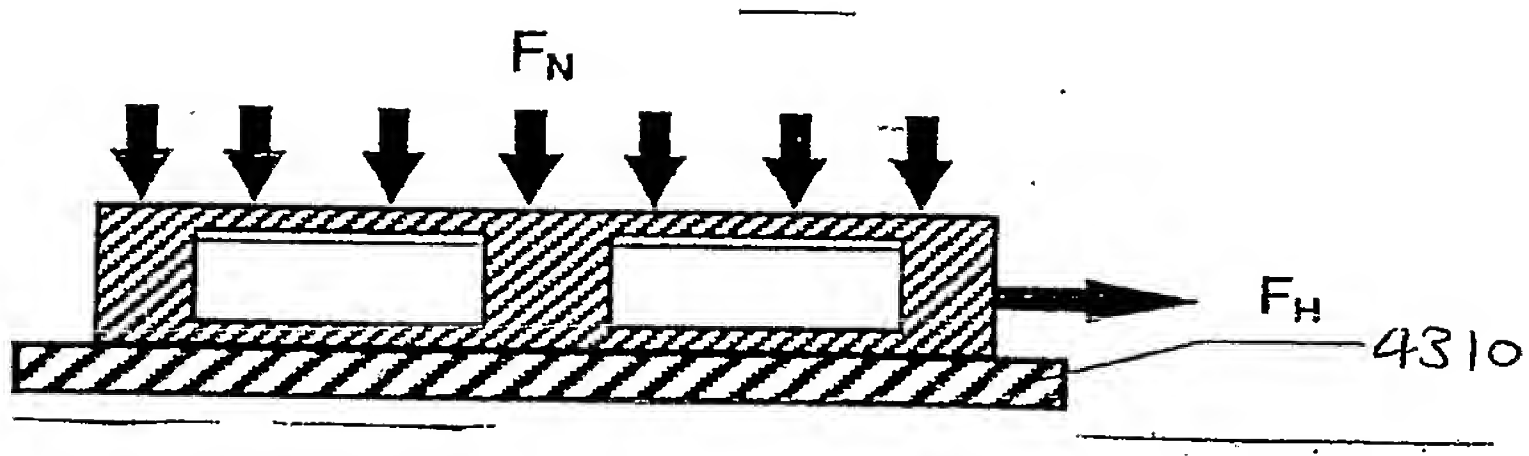


Fig. 43

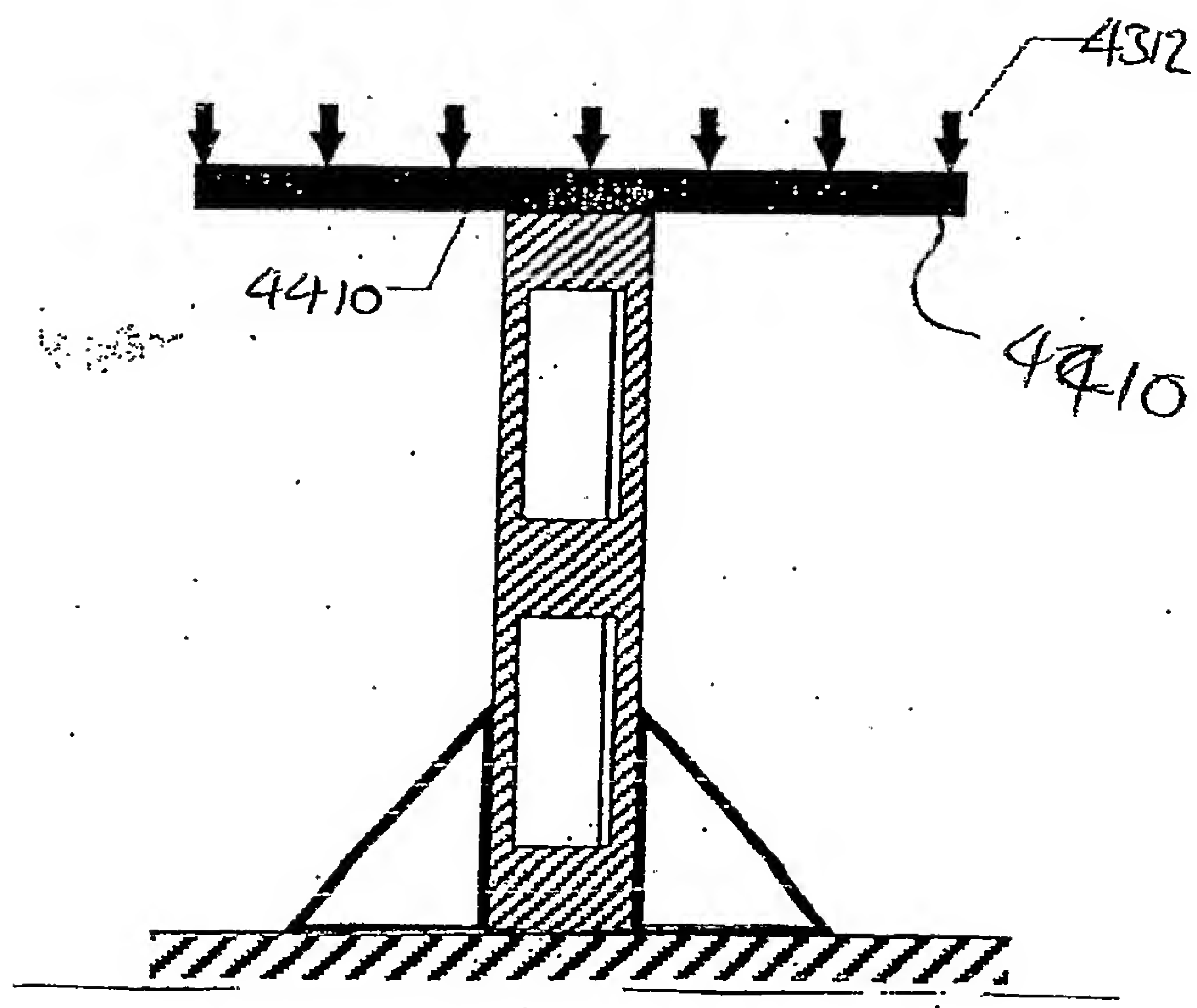


Fig. 44

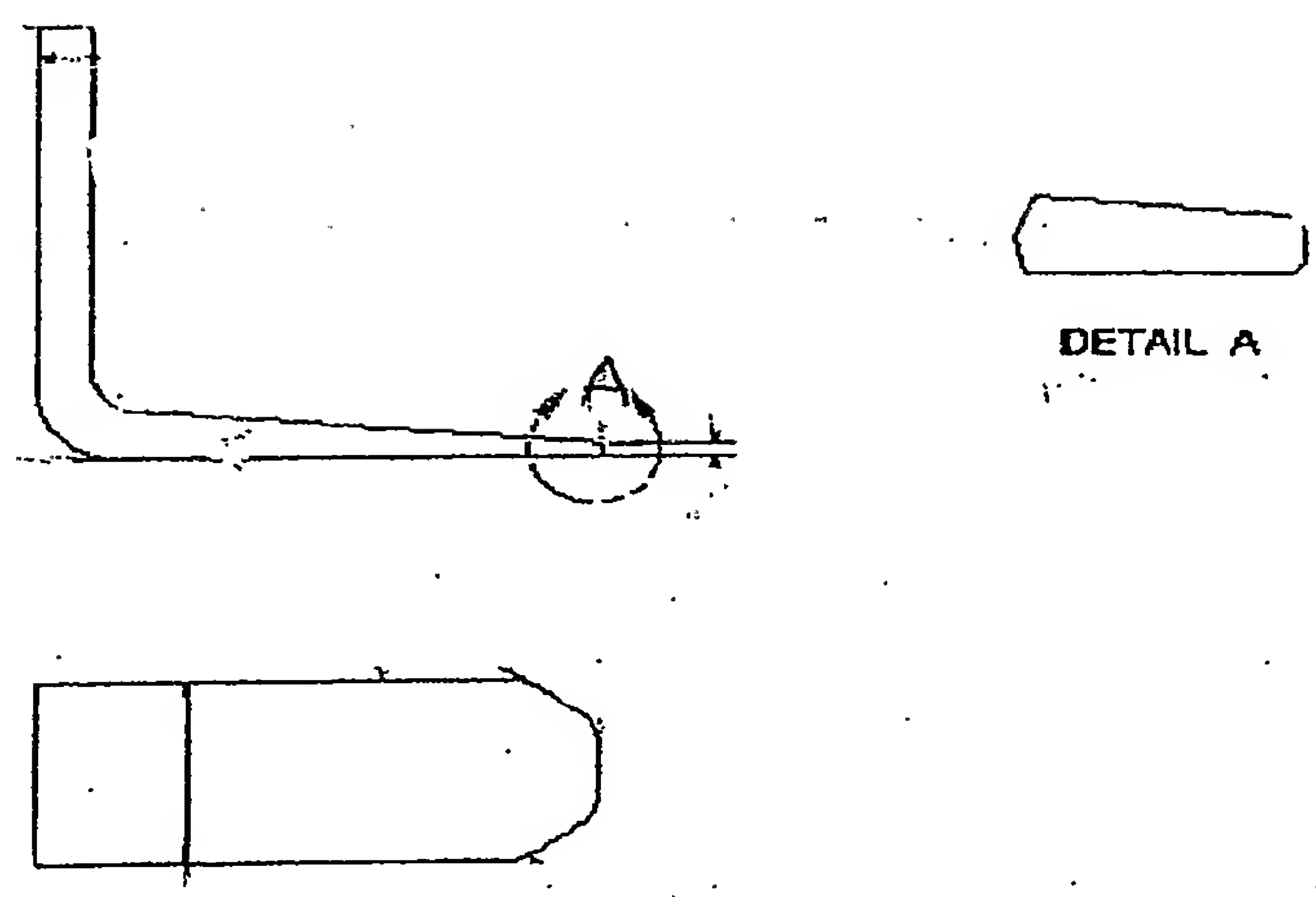


Fig. 45

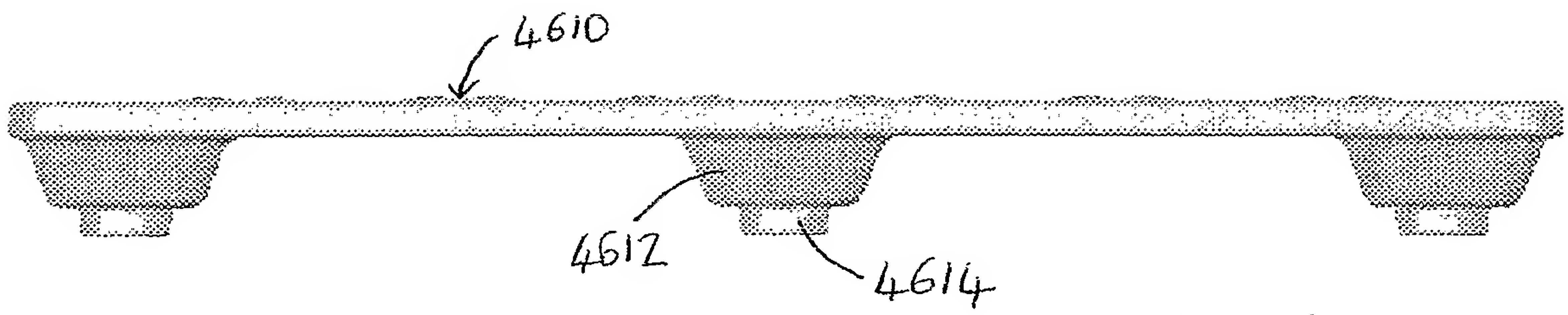


FIG 46

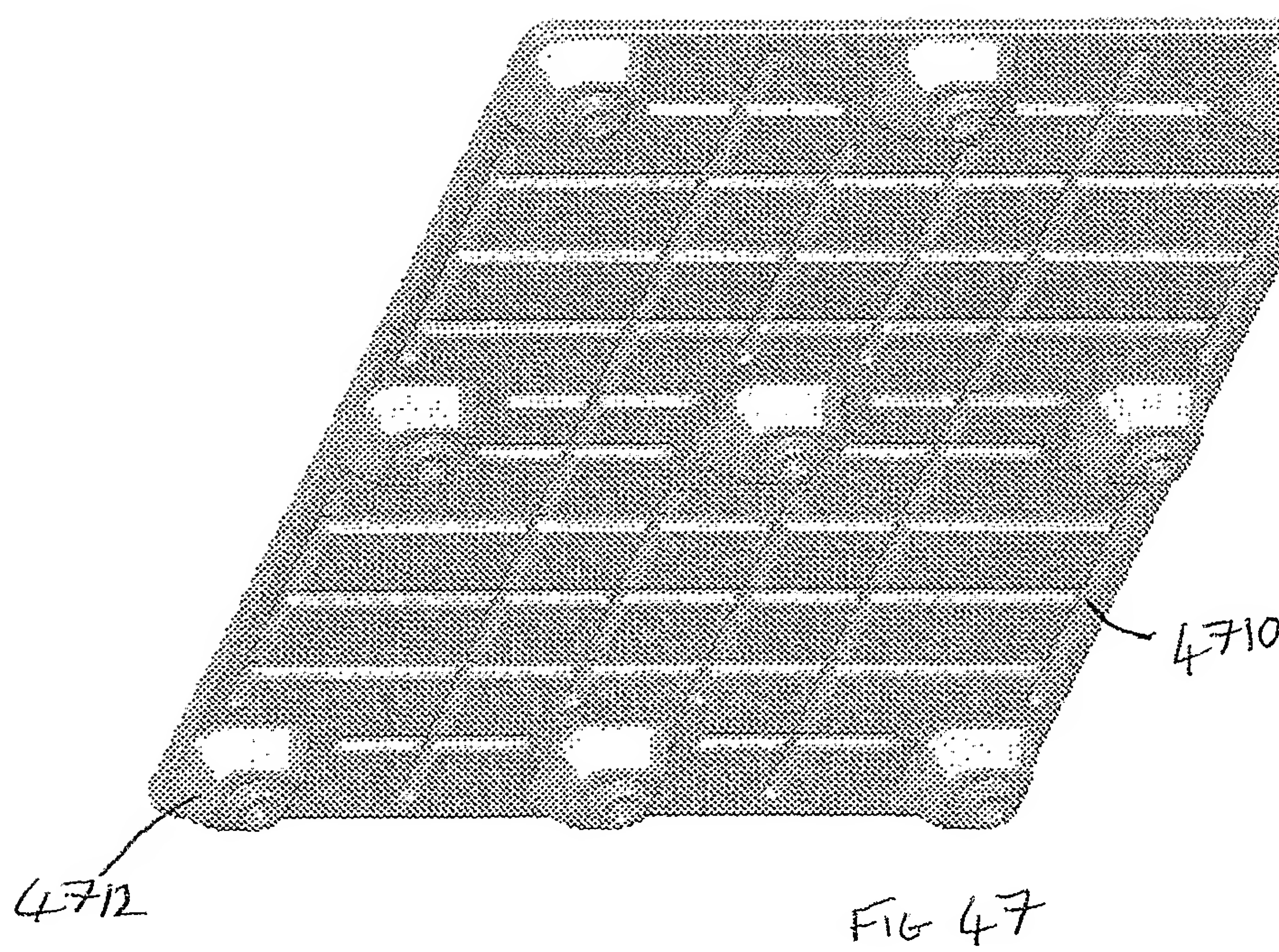


FIG 47

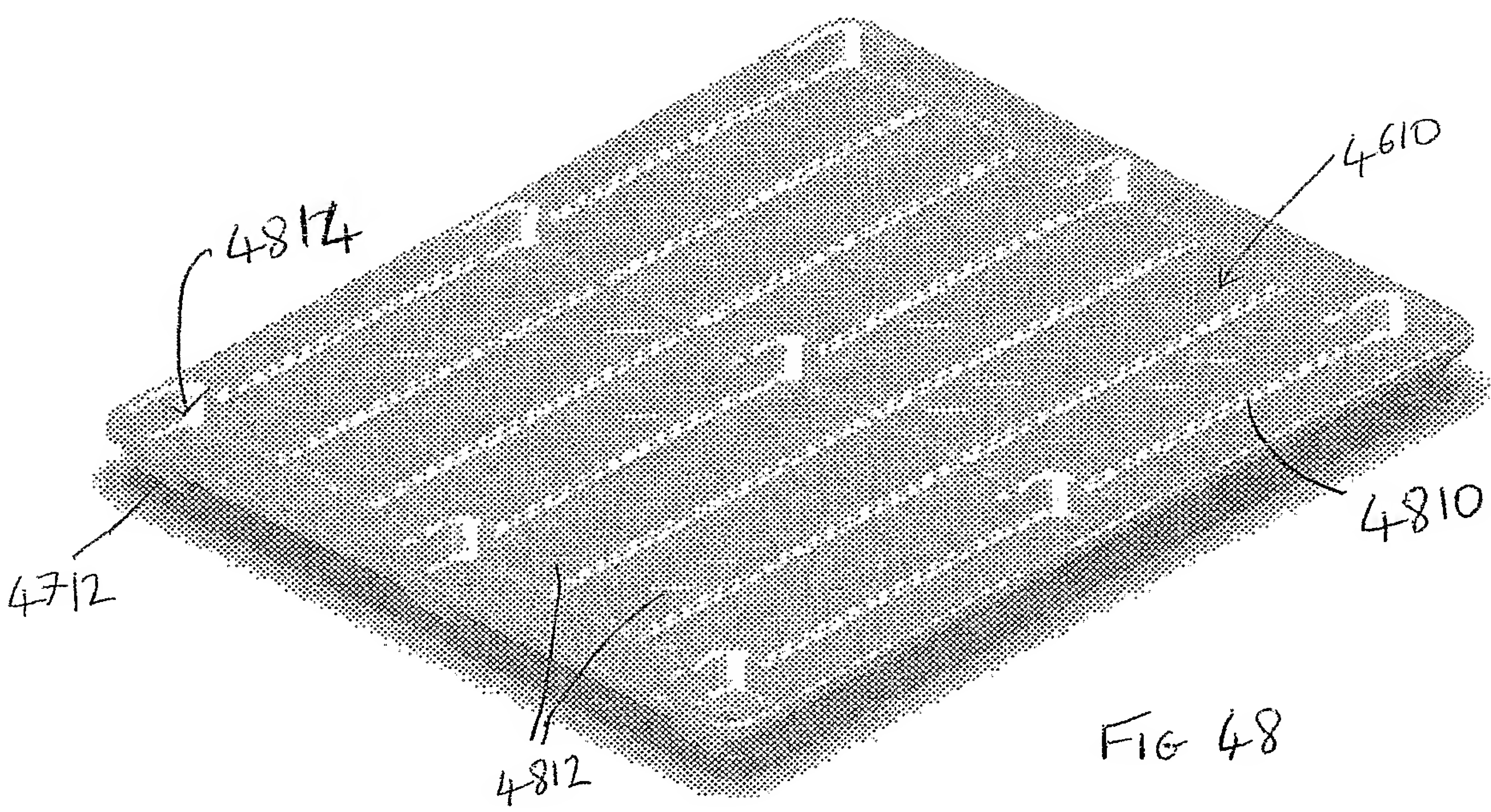


FIG 48

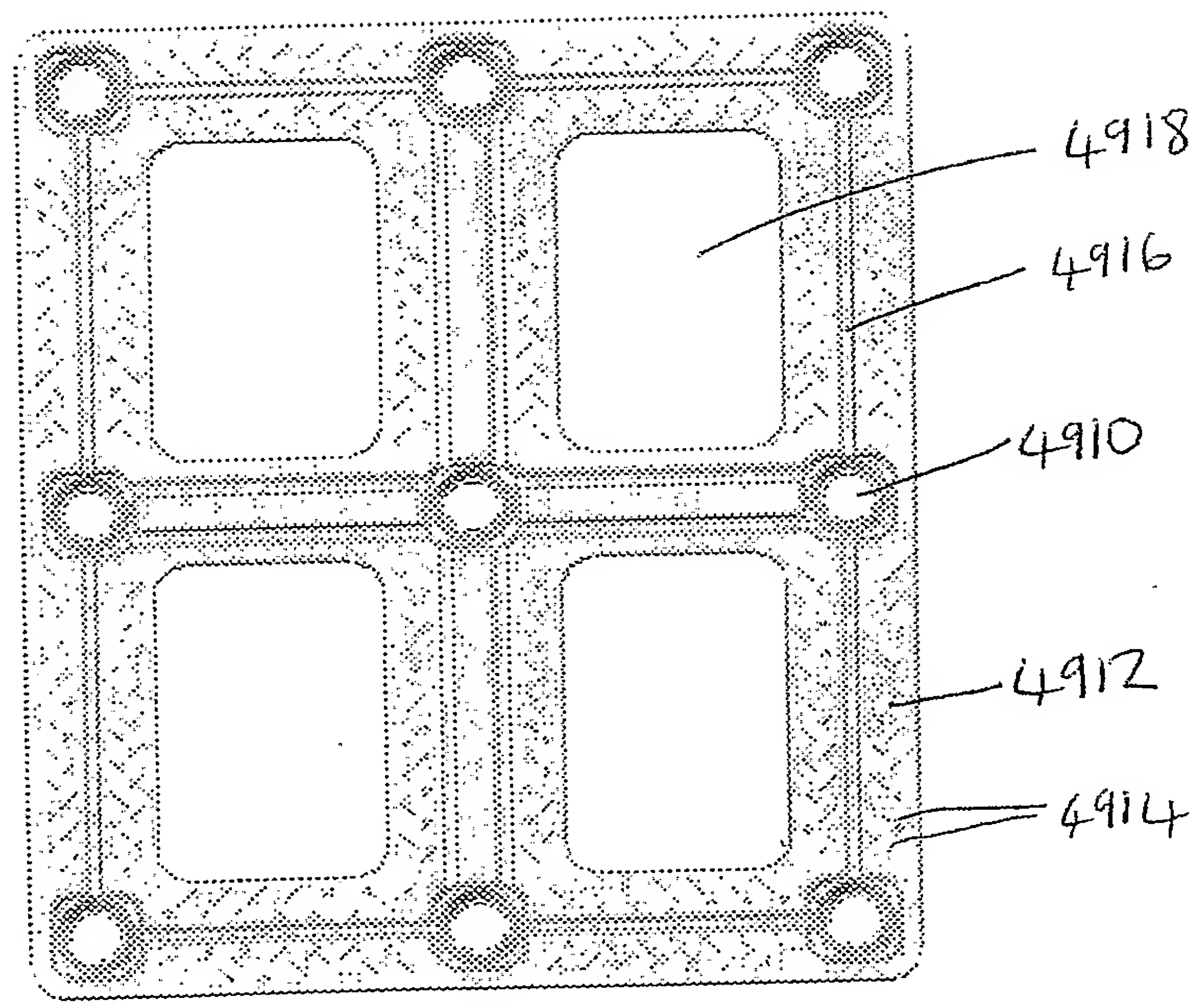


FIG 49

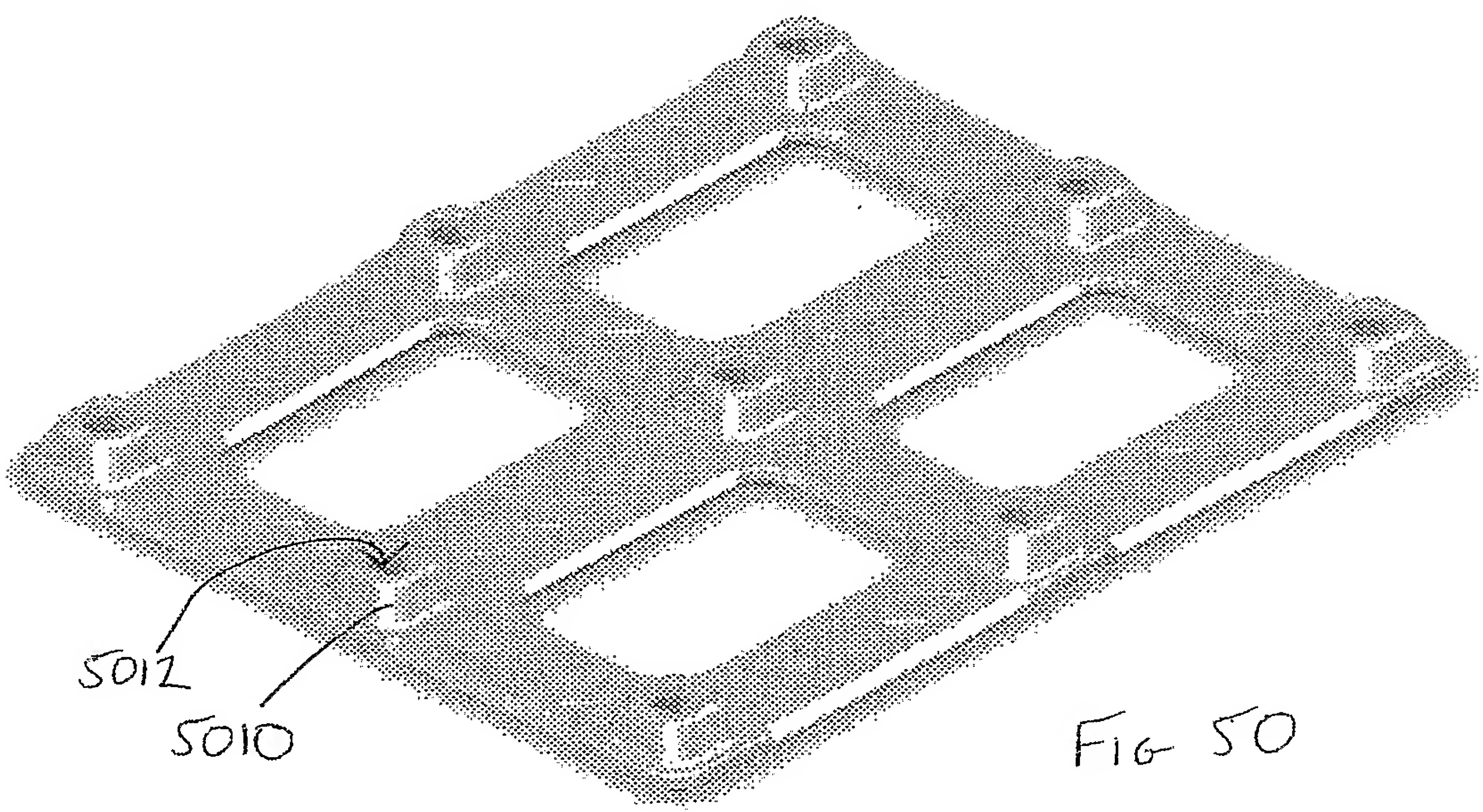


Fig 50

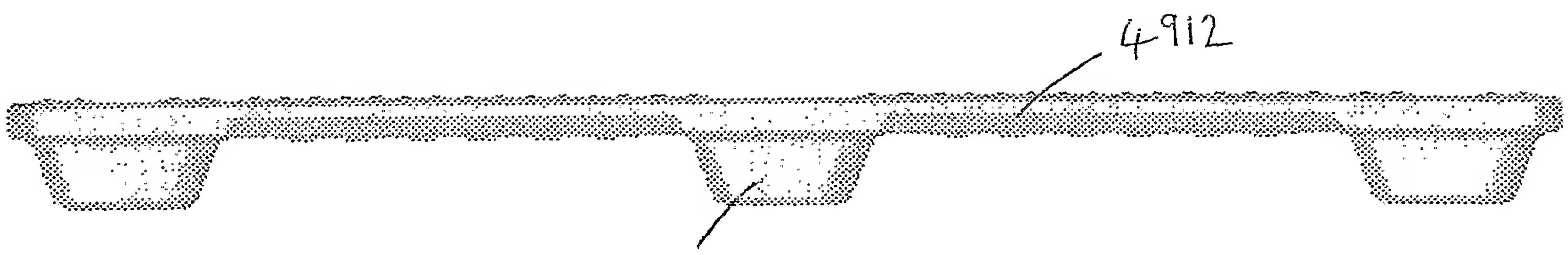


FIG 51

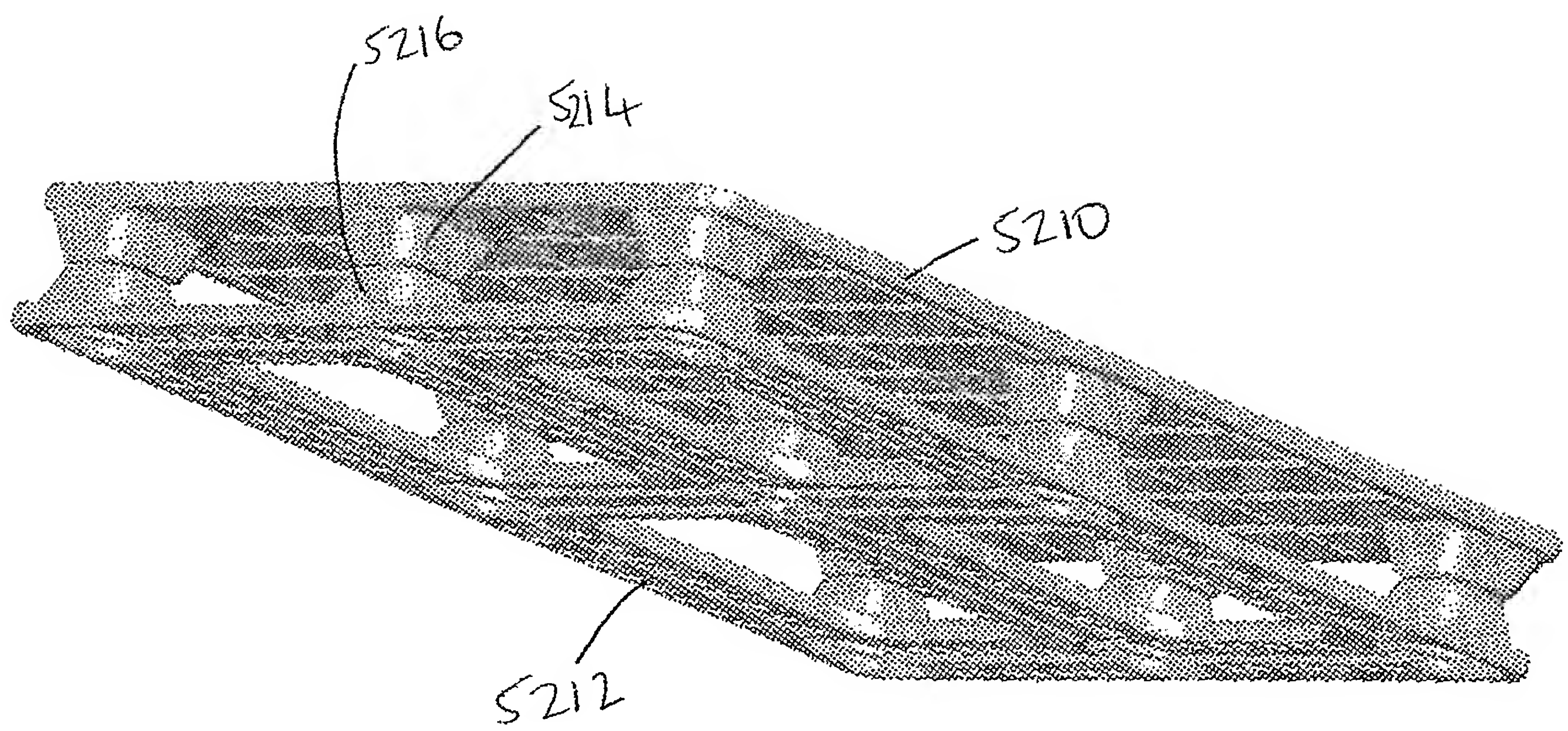


Fig 52

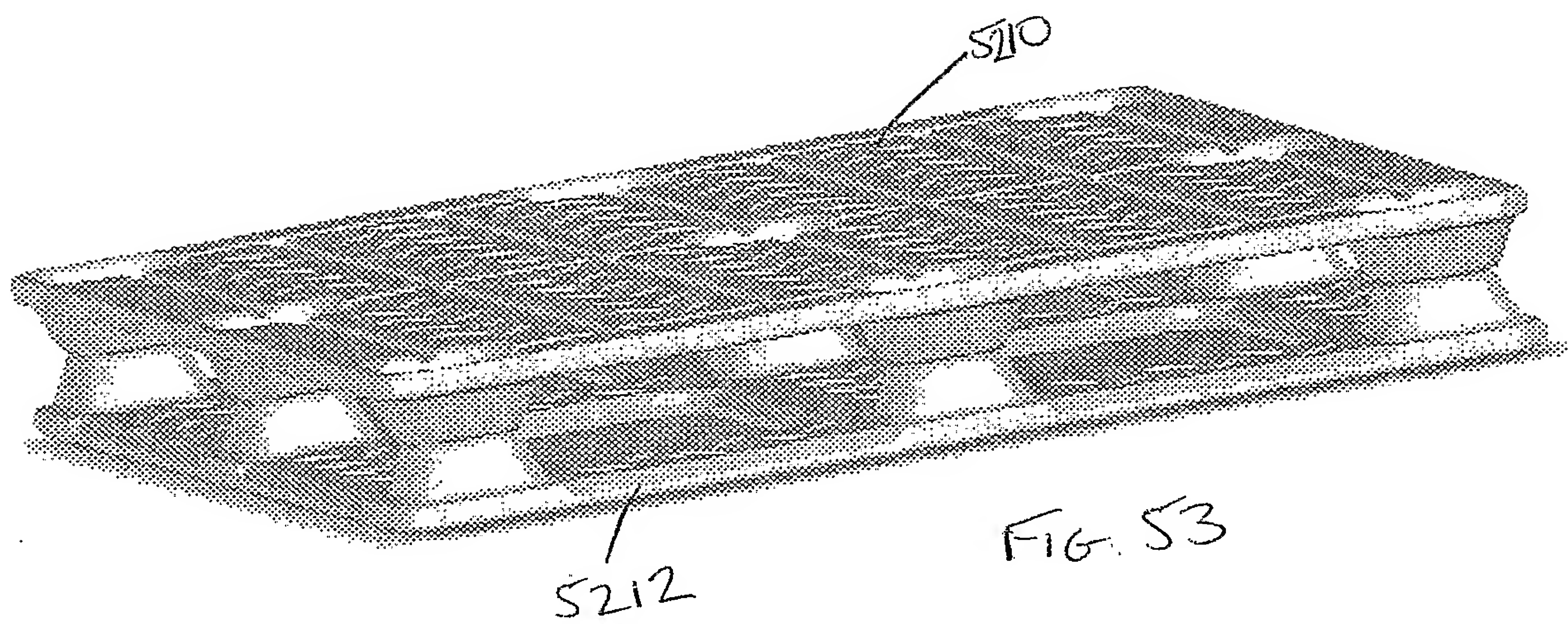


FIG. 53

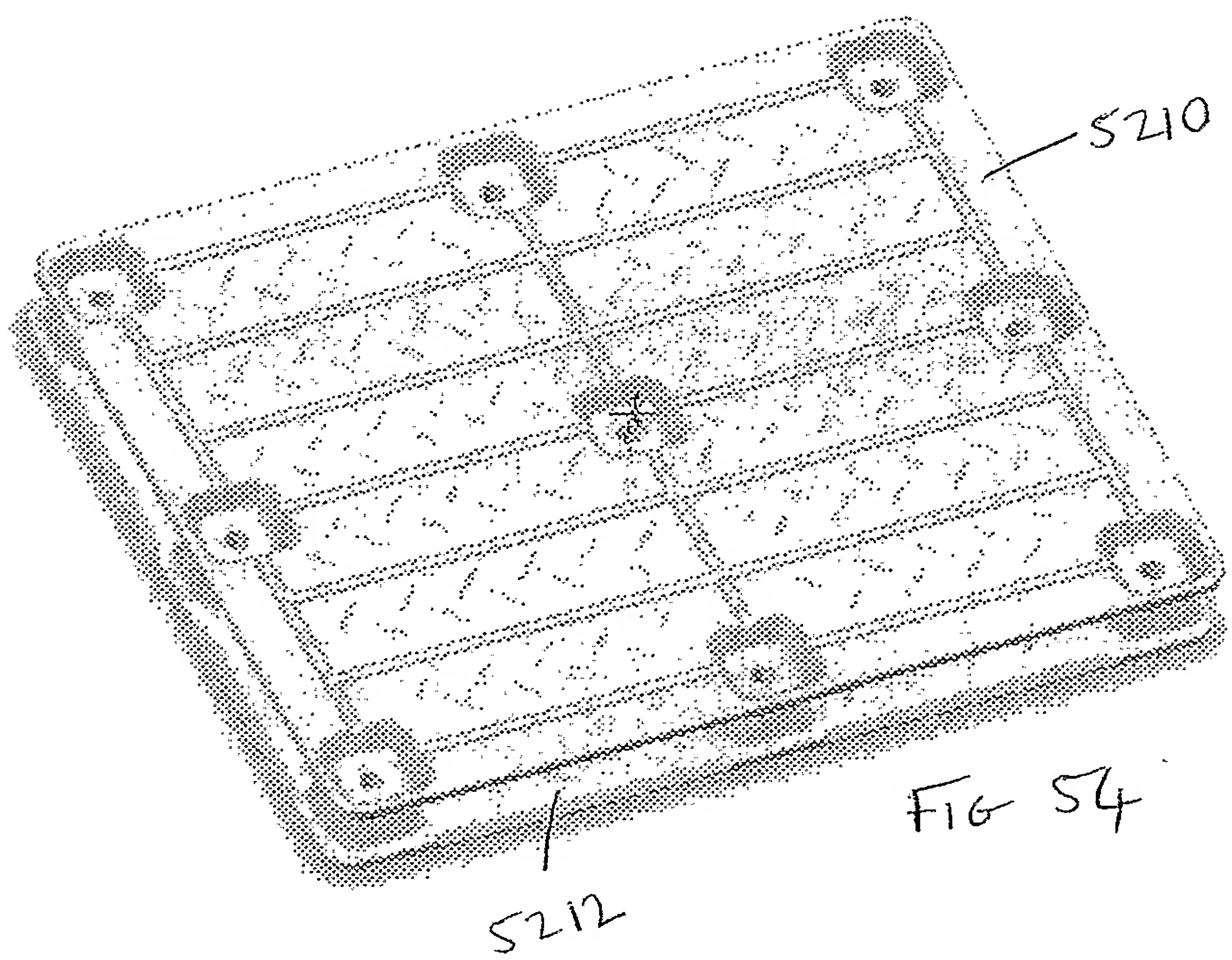


FIG 54

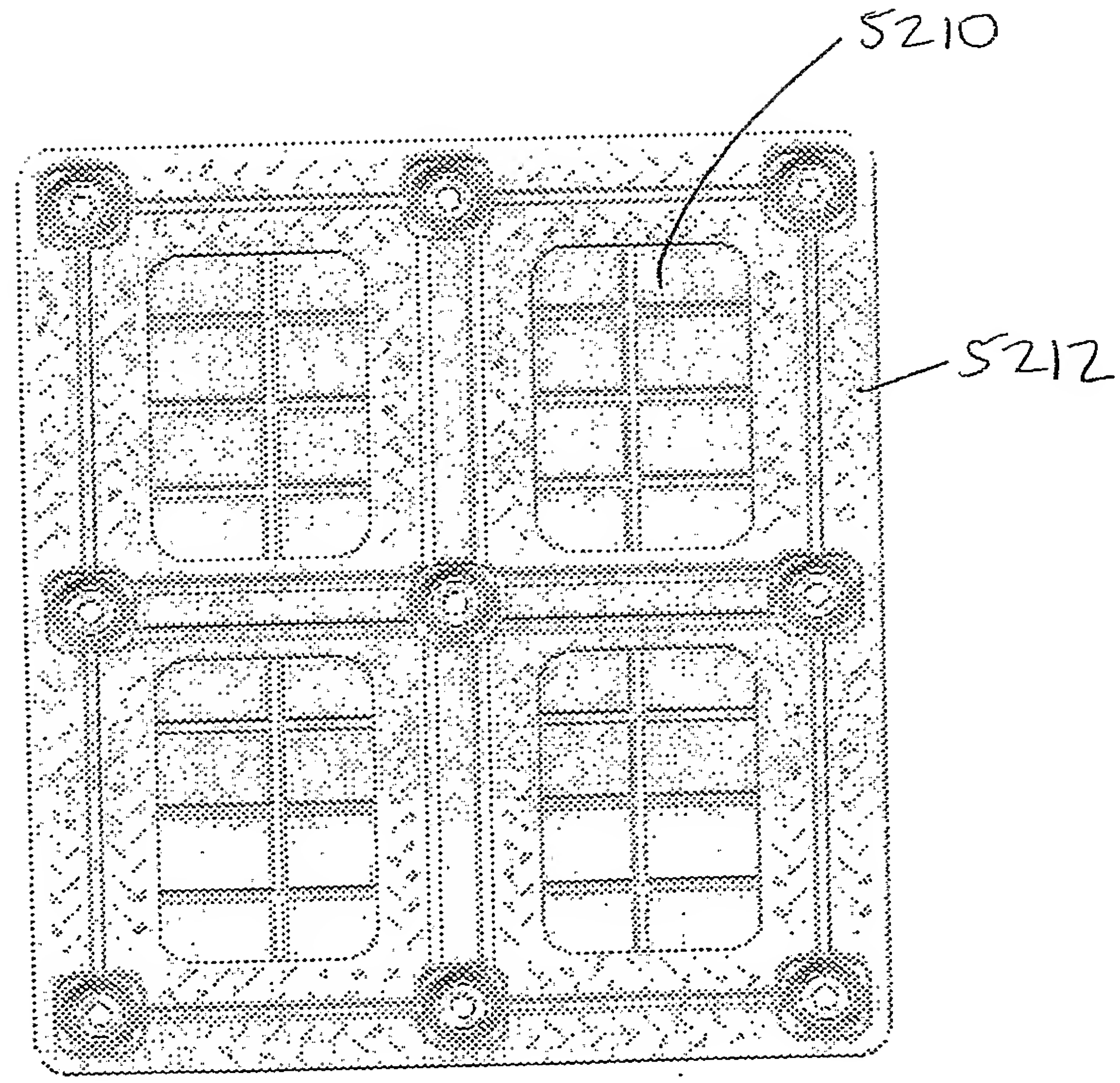


FIG 55

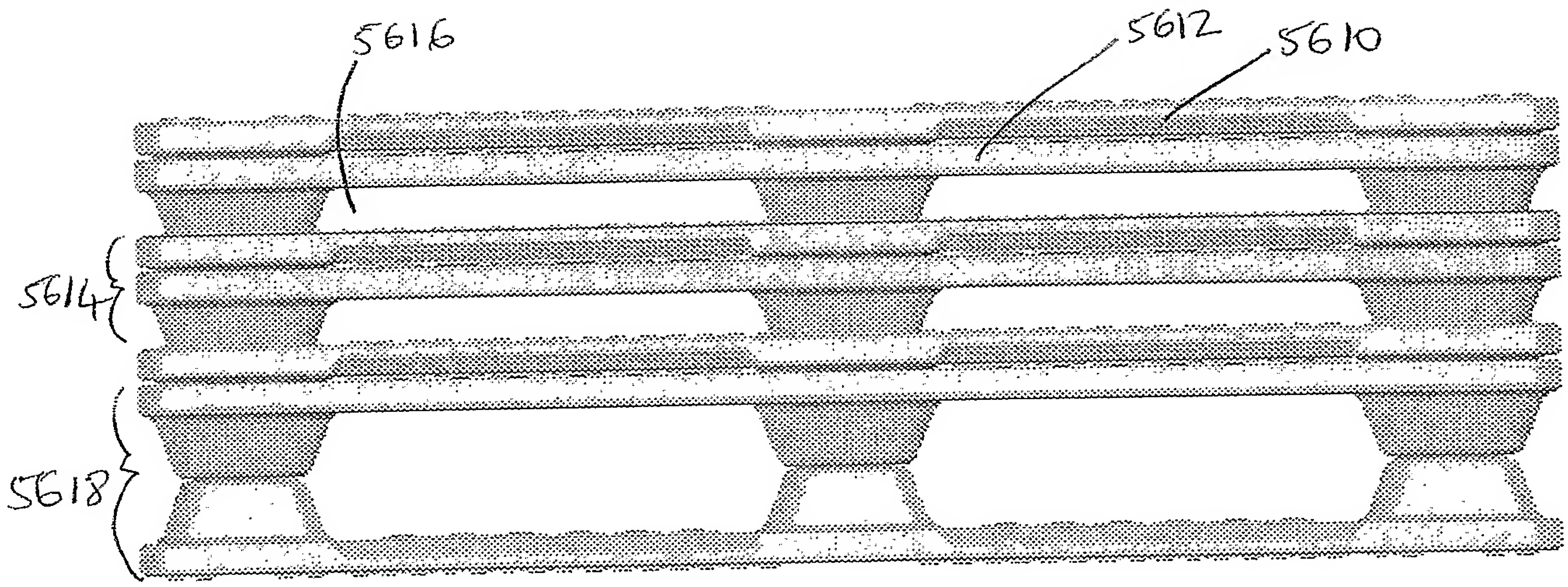


FIG 56

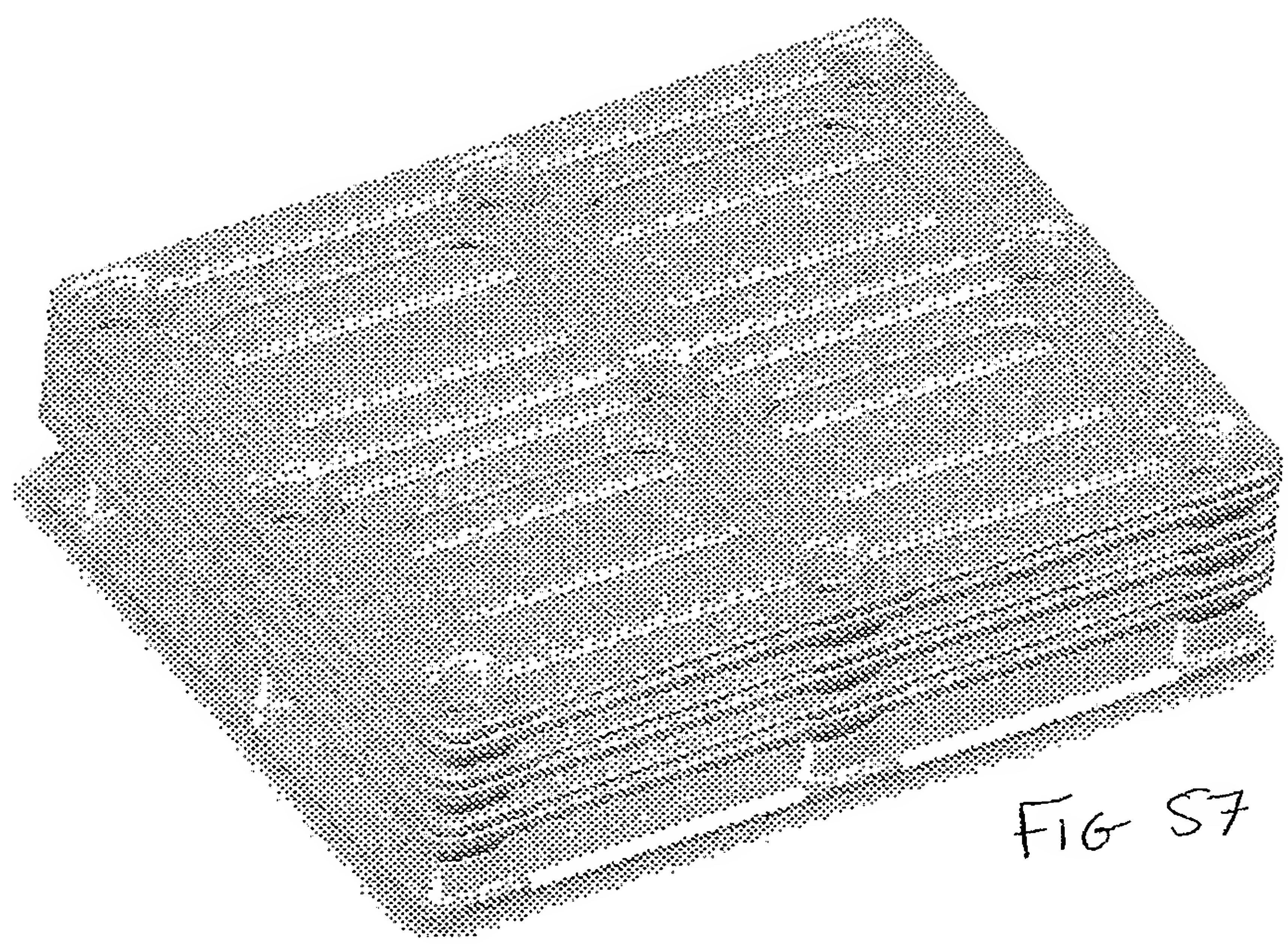


FIG 57

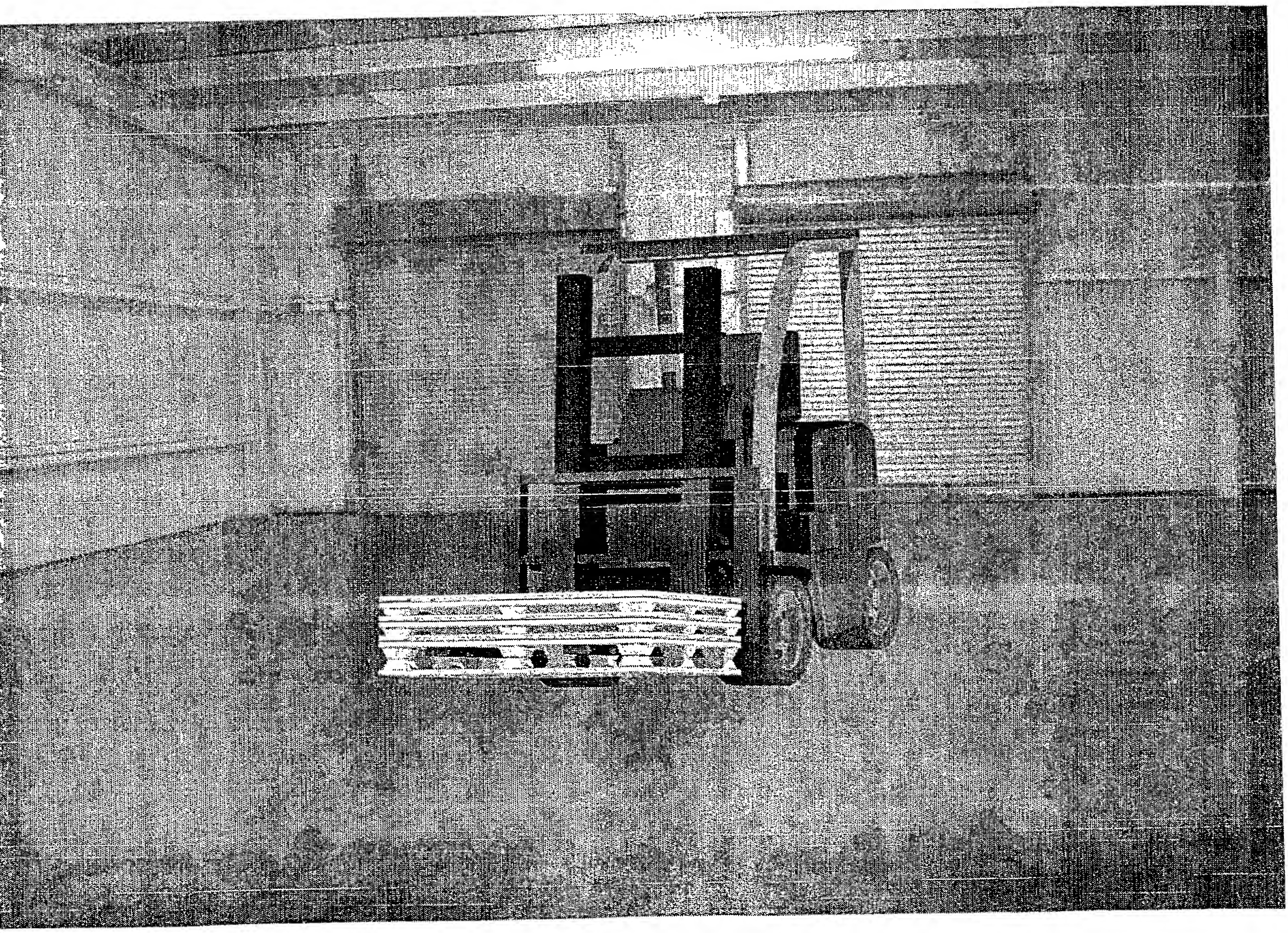


FIG 58